16th International Toki Conference

Advanced Imaging and Plasma Diagnostics

Abstracts

December 5 - December 8, 2006

Toki-city, Japan

The 16th International Toki Conference "Advanced Imaging and Plasma Diagnostics" is the continuation of an annual series that was originally started in 1989, when the National Institute for Fusion Science was established. Each year, selected topics in plasma physics and fusion engineering research have been discussed. ITC-16 will address widely varying topics in the fields of advanced plasma diagnostics and in the fields of imaging sciences such as solar imaging, medical imaging, biological imaging, etc. by bringing together experts from research institutes and from industries.

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ITC16 Program

	12/5 (Tue)			
AM 1	9:00	Registration		
	9:40	Opening		
	10:10	Coffee Break		
AM 2	10:30	1	Plenary	A. Mase
		I1-1	H. Fukuyama	40min.
		I1-2	H. Park	40min.
		O1-3	K. Itoh	20min.
	12:10	Group Photo		
	12:30	Lunch Break		
PM 1	13:50	2	Image Reconstruction	N. Iwama
		I2-1	H. Kudo	30min
		I2-2	J. Hsieh	30min
		I2-3	J. Howard	30min
		I2-4	T. Takeda	30min
	15:50	Coffee Break		
PM 2	16:10	3	Plasma (Imaging Technology)	H. Park
		I3-1	N. Luhmann, Jr	30min
		I3-2	M. Hangyo	30min
		I3-3	G. Etoh	30min
		O3-4	H. Hojo	20min
Evening	18:30	Mayor's Reception for Foreigners		

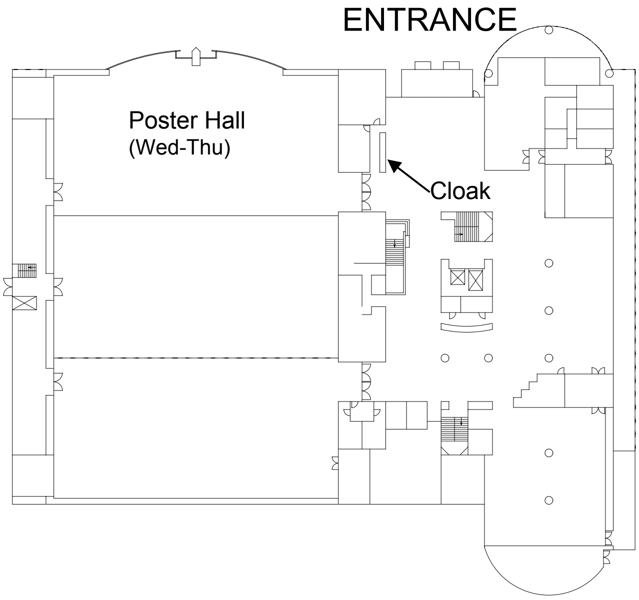
	12/6 (Wed)			
AM 1	9:00	4	Plasma (Particle & Fusion Products)	G. McKee
		I4-1	M. Tanpo	30min
		I4-2	R. Barnsley	30min
		I4-3	H. Bindslev	30min
	10:30	Coffee Break		
AM 2	10:50	5	Electron Microscopy	K. Nagayama
			K. Nagayama	10min
		I5-1	R. Schroeder	25min
		I5-2	N. Mizuno	25min
		I5-3	K. Namba	25min
		I5-4	Y. Kaneko	25min
	12:40	Lunch Break		
PM 1	13:50	Poster (Plasma)		
		Categories 5, 7, 8, 13		
	15:50	Coffee Break		
PM 2	16:10	6	Astronomy (Hinode)	H. Karoji
		I6-1	H. Hara	30min
		I6-2	K. Ichimoto	30min
		I6-3	R. Kano	30min
		I6-4	T. Watanabe	30min
Evening	18:30	Banquet		

	12/7 (Thu)			
AM 1	9:00	7	Plasma（Laser & Particle Beam）	H. Bindslev
		I7-1	Y. Hamada	30min
		I7-2	G. R. McKee	30min
		O7-3	Y. Hatae	20min
		O7-4	K. Kawahata	20min
	10:40	Coffee Break		
AM 2	11:00	8	Medical Imaging	R. Kakigi
		I8-1	Y. Sasaki	30min
		I8-2	N. Sadato	30min
		O8-3	M. Sugiura	20min
		O8-4	T. Iidaka	20min
	12:40	Lunch Break		
PM 1	13:50	Poster (Imaging)		
		Categories 1-4, 6, 9-12		
PM 2	16:00	NIFS Technical Tour		
Evening	18:30	Open Lecture for Citizens		Y. Nagayama
		H. Karoji		45min
		R. Kakigi		45min

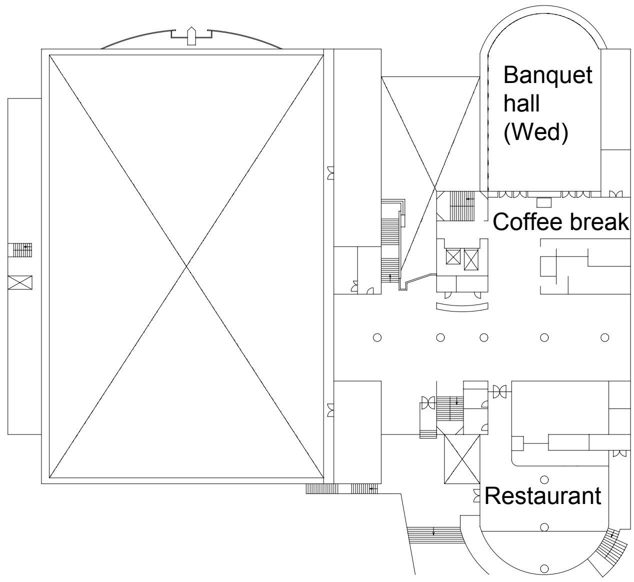
	12/8 (Fri)			
AM 1	9:00	9	Plasma Imaging	J. Howard
		I9-1	S. Ohdachi	30min
		O9-2	Y. Aglitsky	20min
		O9-3	M. Tanabe	20min
		O9-4	B. J. Peterson	20min
	10:30	Coffee Break		
AM 2	10:50	10	Biological Imaging	R. Kodama
		I10-1	E. Stelzer	30min
		I10-2	Y. Ohmiya	20min
		I10-3	T. Nemoto	20min
		I10-4	S. Nonaka	20min
	12:20	Lunch Break		
PM 1	13:30	11	Mix	O. Okamoto
		O11-1	S. Kimura	20min
		O11-2	T. Hasegawa	20min
		O11-3	K. Morita	20min
		O11-4	K. Shibasaki	20min
		O11-5	L. Pranevicius	20min
		O11-6	S. Sudo	20min
PM 2	15:30	Closing		

Ceratopia Toki

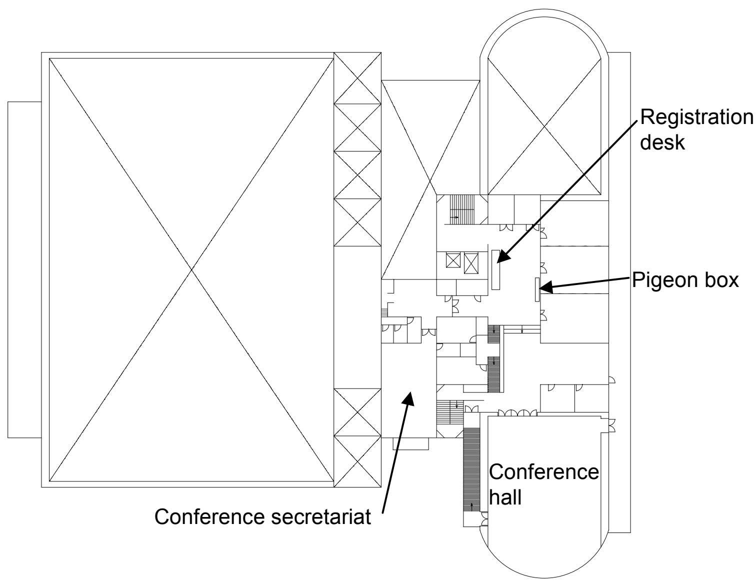
1st floor



2nd floor



3rd floor



Conference Program

DECEMBER 5, 2006 Tuesday

09:00-09:40 **Registration** <2, 3rd Floor>

09:40-10:10 **Opening** <3rd Floor>

-Coffee Break-

Plenary Session <3rd Floor>

Chair: A. Mase

10:30-11:10	**I1-1**	*H. Fukuyama*	Diffusion MRI
11:10-11:50	**I1-2**	*H. Park*	Study of the Complex Physics of the Magnetic Reconnection Process in High Temperature Plasmas using a High Resolution Microwave Imaging System.
11:50-12:10	**O1-3**	*K. Itoh*	On Imaging of Plasma Turbulence

-Group Photo-

-Lunch Break-

Oral Session Image Reconstruction <3rd Floor>

Char: N. Iwama

13:50-14:20	**I2-1**	*H. Kudo*	A Comprehensible Review on Analytical Image Reconstruction Methods for Tomography
14:20-14:50	**I2-2**	*J. Hsieh*	Present and Future of Computed Tomography Technology
14:50-1520	**I2-3**	*J. Howard*	Optical coherence imaging for high resolution plasma spectroscopy
15:20-15:50	**I2-4**	*T. Takeda*	Ionospheric Tomography by Neural Network Collocation Method

-Coffee Break-

Oral Session Plasma(Imaging Technology) <3rd Floor>

Chair:H. Park

16:10-16:40	**I3-1**	*N. Luhmann, Jr*	Advanced Microwave/Millimeter-Wave Imaging Technology
16:40-17:10	**I3-2**	*M. Hangyo*	Spectroscopy and Imaging by Laser Excited Terahertz Waves

17:10-17:40	**I3-3**	*G. Etoh*	Evolution of Ultra-High-Speed CCD Imagers
17:40-18:00	**O3-4**	*H. Hojo*	Simulation Studies on Advanced Microwave Diagnostics and Related Technology

18:30-20:30 **Mayor's Reception for Foreign Participants**

DECEMBER 6, 2006 Wednesday

Oral Session Plasma(Particle & Fusion Products) <3rd Floor>

Chair: G. McKee

9:00-9:30	**I4-1**	*M. Tanpo*	High density plasma probing with pulse proton beams generated in ultra-intense laser plasma interactions
9:30-10:00	**I4-2**	*R. Bamsley*	Advanced imaging applications on ITER
10:00-10:30	**I4-3**	*H. Bindslev*	The diagnosis of fast ions in fusion plasmas by means of collective Thomson scattering (CTS)

-Coffee Break-

Oral Session Electron Microscopy <3rd Floor>

Chair: K. Nagayama

10:50-11:00		*K. Nagayama*	Introduction
11:00-11:25	**I5-1**	*R. Schroeder*	Optimizing Phase Contrast in TEM by the use of an electrostatic Boersch Phase Plate
11:25-11:50	**I5-2**	*N.Mizuno*	Cryo-EM study of dynein-microtubule interaction
11:50-12:15	**I5-3**	*K. Namba*	Molecular Mechanisms of Swimming and Tumbling in Bacterial Motility
12:15-12:40	**I5-4**	*Y. Kaneko*	Visualization of in vivo macromolecules in ice embedded whole cyanobacterial cells by Hilbert differential contrast transmission electron microscopy.

-Lunch Break-

Poster Session I (Plasma) <1st Floor>

P5-01~P5-20, P7-01~P7-19, P8-01~P8-32, P13-1~P13-7

-Coffee Break-

Oral Session Astronomy(Hinode) <3rd Floor>

Chair: H. Karoji

16:10-16:40	**I6-1**	*H. Hara*	Hinode; A New Solar Observatory in Space - Current Status -
16:40-17:10	**I6-2**	*K. Ichimoto*	Three-Dimensional Magnetic Structures of Solar Photosphere and Chromosphere
17:10-17:40	**I6-3**	*R. Kano*	Multiplicity of Solar X-Ray Corona in Time and Space
17:40-18:10	**I6-4**	*T. Watanabe*	Emission Line Imaging Spectroscopy for Diagnosing of Solar Outer Atmospheres

18:30-20:30 **Banquet** <2nd Floor>

DECEMBER 7, 2006 Thursday

Oral Session Plasma(Laser & Particle Beam) <3rd Floor>

Chair: H. Bindslev

9:00-9:30	**I7-1**	*Y. Hamada*	Heavy Ion Beam Probe, Present status and future development
9:30-10:00	**I7-2**	*G. R. McKee*	Plasma Turbulence Imaging via Beam Emission Spectroscopy on the DIII-D Tokamak
10:00-10:20	**O7-3**	*Y. Hatae*	Development of Polarization Interferometer Based on Fourier Transform Spectroscopy for Thomson Scattering Diagnostics
10:20-10:40	**O7-4**	*K. Kawahata*	Advanced Laser Diagnostics for Electron Density Measurements.

-Coffee Break-

Oral Session Medical Imaging <3rd Floor>

Chair: R. Kakigi

11:00-11:30	**I8-1**	*Y. Sasaki*	MRI technologies in recent human brain mapping
11:30-12:00	**I8-2**	*N. Sadato*	Cross-modal integration and plasticity revealed by functional magnetic resonance imaging
12:00-12:20	**O8-3**	*M. Sugiura*	Cortical Networks for Visual Self-Recognition
12:20-12:40	**O8-4**	*I. Iidaka*	Neuroimaging Study of the Human Amygdala-Toward an Understanding of Emotional and Stress Responses-

-Lunch Break-

Poster Session II (Imaging) <1st Floor>

P1-01~P4-03, P6-01~P6-39, P9-01~P12-6

-Coffee Break-

16:00-18:00 **Technical Tour To NIFS**

18:30-20:30 **Open Lectures to Citizens**

DECEMBER 8, 2006 Friday

Oral Session Plasma(Plasma Imaging) <3rd Floor>

Chair: J. Howard

9:00-9:30	**I9-1**	*S. Ohdachi*	Tangential SX imaging for visualization of fluctuations in toroidal plasmas
9:30-9:50	**O9-2**	*Y. Aglitskiy*	Monochromatic x-ray imaging and spectroscopy with spatial resolution for ICF experiments
9:50-10:10	**O9-3**	*M. Tanabe*	X-ray spectroscopic diagnostics for laser-imploded core plasmas with high spatial and temporal resolutions
10:10-10:30	**O9-4**	*B. J. Peterson*	Research and Development of Imaging Bolometers

-Coffee Break-

Oral Session Biological Imaging <3rd Floor>

Chair: R. Kodama

10:50-11:20	**I10-1**	*E.Stelzer*	Farewell cover slip: Light-sheet based microscopy (SPIM) fosters a modern approach to three-dimensional cell biology
11:20-11:40	**I10-2**	*Y. Ohmiya*	Imaging of cell functions using by bioluminescence probes
11:40-12:00	**I10-3**	*T. Nemoto*	Functional Imaging of Neural Cell and Secretory Gland Cell by Near-infrared Ultra-short Pulse Laser Light
12:00-12:20	**I10-4**	*S. Nonaka*	Symmetry break in developmentmental biology: Left-right determination.

-Lunch Break-

<u>*Oral Session Mix*</u> <3rd Floor>

Chair: O. Okamoto

13:30-13:50	**O11-1**	*S. Kimura*	Infrared magneto-optical imaging on an organic conductor by means of synchrotron radiation
13:50-14:10	**O11-2**	*T. Hasegawa*	Atacama Large Millimeter/Submillimeter Array ALMA
14:10-14:30	**O11-3**	*K. Morita*	Imaging Technique of Radio Interferometers
14:30-14:50	**O11-4**	*K. Shibasaki*	Multi-wavelength Imaging of Solar Plasma
14:50-15:10	**O11-5**	*L. Pranevicius*	Carbon redeposition under high-flux, low-energy ion irradiation effects on properties of tungsten films
15:10-15:30	**O11-6**	*S. Sudo*	Multi-functional Diagnostic Method with Tracer-encapsulated Pellet Injection

15:30-16:00 **Closing**

Poster Session 1 – Plasma (Categories 5, 7, 8)

P5-01 Electron Temperature Measurement And Study Of Istabilities And Sawtooth Behavior In IR-T1 Tokamak By E.C.E Diagnostic
Reza Shariatzadeh, Plasma Physics Reaserch Center,Islamic Azad University

P5-02 Effects of relativistic and absorption on ECE spectra in high temperature tokamak plasma
Masayasu Sato , Japan Atomic Energy Agency,Naka Fusion Institute

P5-03 Suprathermal electron distribution diagnostic for SST-1 tokamak
Surya Kumar Pathak, Institute for Plasma Research

P5-04 Protection Filters in ECEI Systems for Plasma Diagnostics
Luhmann,jr. C. Neville, University of California, Davis, US

P5-05 Imaging meso-scale structures in TEXTOR
Roger Jaspers, FOM institute of Plasma Physics Rijnhuizen

P5-06 Development of ECE Imaging System on LHD
Yuichiro Kogi, Art,Science and Technology Center for Cooperative Reserch, Kyushu University

P5-07 Improvements of CO2 laser heterodyne imaging interferometer for density profile measurements on LHD
Kenji Tanaka, National Institute for Fusion Science

P5-08 Two dimensional phase contrast imaging of micro-turbulence in LHD
Clive Alvin Michael, National Institute for Fusion Science

P5-09 Instrumental capabilities and limitations of two-dimensional phase contrast imaging on LHD
Leonid Nikolaevich Vyacheslavov, Budker Institute for Nuclear Physics

P5-10 Electron Density Measurement by Using a Multi-Channel Interferometer System in the Tandem Mirror GAMMA 10
Masayuki Yoshikawa, University of Tsukuba

P5-11 Reflectometry for Density Fluctuation and Profile Measurements in TST-2
Takuma Yamada, Research Institute for Applied Mechanics, Kyushu University

P5-12 Microwave Imaging Reflectometry in LHD
Soichiro Yamaguchi, National Institute for Fusion Science

P5-13 Multi-channel Microwave Reflectometer with Fermi Antenna Receivers
Kunihiko Hattori, Department of Electrical Engineering, Graduate School of Engineering, Tohoku University

P5-14 Design of the 48, 57 μ m Poloidal Polarimeter for ITER
Rostyslav Pavlichenko, National Institute for Fusion Science

P5-15 Weakly Relativistic K-band Oversized Backward Wave Oscillator with Bragg Reflector at Input End of Slow Wave Structure
Kazuo Ogura, Graduate School of Science and Technology, Niigata University

P5-16 Advanced Fabrication Method of Planar Components for Plasma Diagnostics
Naoki Ito, Art, Science and Technology Center for Cooperative Research, Kyushu University, Japan

P5-17 Development of a Tera Hertz Gyrotron as a Radiation Source
Osamu Watanabe, Plasma Research Center, University of Tsukuba

P5-18 Utilization of Terahertz Imaging Technology to High-Temperature Plasma Diagnostics
Tokihiko Tokuzawa, NIFS

P5-19 Laser Absorption Spectroscopy for Diagnostics of a Neutral Helium Beam
Atsushi Okamoto, Tohoku University

P5-20 Design of bolometer diagnostics for the KSTAR
Dongcheol Seo, National Fusion Research Center

P7-01 Helium measurements using the pellet charge exchange in Large Helical Device
Tetsuo Ozaki, National Institute for Fusion Science

P7-02 New 20-channel Diagnostic for Angle-Resolved Fast Particles Measurements in LHD.
Evgeny A Veshchev, SOKENDAI, Ph.D. student

P7-03 A Method for Reconstruction of the Neutral Particle Source Function in Helical Magnetically Confined Plasma
Pavel R. Goncharov, National Institute for Fusion Science

P7-04 Analysis of energy spectra of fast ion in the Large Helical Device
Hidetoshi Nishimura, Department of Quantum Science and Energy Engineering, Tohoku University

P7-05 Fast ion diagnostics for CHS experiment
Mitsutaka Isobe, National Institute for Fusion Science

P7-06 Effects of Radially Sheared Electric Field Analyzed with End-Loss Ion-Energy Spectrometers
Mafumi Hirata, Plasma Research Center, University of Tsukuba

P7-07 Use of γ-ray-generating ^{6}Li+D reaction for verification of Boltzmann-Fokker-Planck simulation and knock-on tail diagnostics in neutral-beam-injected plasmas
Hideaki Matsuura, Kyushu University

P7-08 Observation of Molecular and Atomic Ions in recombination Plasma
Akira Tonegawa, Department of Physics, School of Science, Tokai University

P7-09 Observation of Divertor Plasma Shift during a Discharge in Heliotron J
Tohru Mizuuchi, Institute of Advanced Energy, Kyoto University

P7-11 Measurement of gas composition ratio of H-He mixture plasmasin Divertor Simulator MAP-II
Yosuke Kuwahara, Department of Quantum Eng. and Systems Sci., School of Engeenering, The University of Tokyo

P7-12 Development of Heat Flow Measurement using Thermal Probe Method in Divertor Simulator MAP-II
Kiminori Kurihara, School of Engineering, The university of Tokyo

P7-13 Development of a neutron measurement system for nd/nt fuel ratio measurement in burning plasma
Koichi Okada, Tohoku University

P7-14 Neutron spectral broadening due to the polyethylene collimator of the fast neutron spectrometer
Tetsuro Matsumoto, National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technolgy

P7-15 Characteristic observation of the ion beams in the plasma focus device
Hamid reza Yousefi, University of Toyama

P7-16 Development of a Simple and Tough Alpha-particle Detector Used at High Temperature
Toshiyuki Iida, Osaka University

P7-17 Effects of ion orbits due to potential formation on transverse ion transport in thethermal barrier region of GAMMA10
Hiroshi Saimaru, Plasma Research Center, University of Tsukuba

P7-18 The Neutral Transport Analysis Based on Visible Light Measurement of Recycling and 3-dimensional Simulation in GAMMA 10
Yuta Higashizono, Plasma Research Center, University of Tsukuba

P7-19 Calculation of Fusion Condition of Hydrogen-Boron by I.C.F Method
Babak Malekyneia, Plasma Physics Research Center, Islamic Azad University

P8-01 Sheath Structure around Negatively Biased Probe in Electronegative Plasma
Hiroto Matsuura, Osaka Prefecture University

P8-02 Electron Energy Distribution Functions in a Low Pressure Inductively Coupled CH4/H2 Plasma
Katsuyuki Okada, National Institute for Materials Science

P8-04 Advanced Probe Measurement System in TU-Heliac
Yutaka Tanaka, Department of Quantum Science and Energy Engineering, Tohoku University

P8-05 Mach Probe Measurements of Detached Plasmas in a Linear Plasma Device
Naomichi Ezumi, Nagano National College of Technology

P8-06 Measurement of Electron Density and Temperature and Their Fluctuations Using a Triple Langmuir Probe Grounded through Finite Resistance
Masaki Takeuchi, Department of Energy Engineering and Science, Nagoya University

P8-07 Calibration of Fast Ion Flux Measured by a Directional Probe
Kenichi Nagaoka, National Institute for Fusion Science

P8-08 Probing of toroidal electron plasmas confined in CHS magnetic surfaces
Yoshiaki Yamamoto, Kyoto Institute of Technology, Department of Electronics

P8-09 Technique of MHD mode analysis using magnetic measurements in heliotron plasmas
Satoru Sakakibara, National Institute for Fusion Science

P8-10 Magnetic Diagnostics of Magnetic Island in LHD
Yoshiro Narushima, National Institute for Fusion Science (NIFS)

P8-11 Current Profile Dependence of CCS Method to Reproduce Spherical Tokamak Plasma Shape
Wang Feng, AEES, Kyushu University

P8-12 Two-dimensional edge density measurements in the Large Helical Device
Hayato Tsuchiya, Graduate University for Advanced Studies

P8-13 Measurement of 3-D Mode Structure of the Edge Harmonic Oscillations in CHSusing Beam Emission Spectroscopy
Tetsutarou Oishi, National Institute for Fusion Science

P8-14 Potential measurement with 6 MeV Heavy Ion Beam Probe on LHD
Akihiro Shimizu, NIFS

P8-15 Estimate of ionization cross sections for a heavy ion beam probe
Masaki Nishiura, National Instiute for Fusion Science

P8-17 Structure of sample volumes of the heavy ion beam probe in LHD
Takeshi Ido, National Institute for Fusion Science

P8-18 Observation of the effects of radially sheared electric fields by the use of a gold neutral beam probe
Yoshiaki Miyata, Plasma Research Center, University of Tsukuba

P8-19 Beam Probe Imaging Method for Edge Plasma Modeling in CHS
Harukazu Iguchi, National Institute for Fusion Science

P8-20 Two dimensional Li beam imaging to study the magnetic field configuration effects on plasma confinement in spherical tokamak CPD
Rajendraprasad Bhattacharyay, Interdisciplinary Graduate School of Engineering Science, Kyushu University

P8-21 Numerical Simulation of a High-Brightness Lithium Ion gun for a Zeeman Polarimetry on JT-60U
Atsushi Kojima, Japan Atomic Energy Agency

P8-22 Proof of principle experiment of a fast He0 beam production for alpha particle diagnostics
Nozomi Tanaka, Tohoku University, Department of Quantum Science and Energy Engineering

P8-23 Raman and Rayleigh Calibrations of the LHD YAG Thomson Scattering
Yamada Ichihiro, National Institute for Fusion Science

P8-24 Improving the Thomson Scattering Diagnostic installed on the Large Helical Device
Kazumichi Narihara, National Institute for Fusion Science

P8-25 Development of 2-D Thomson Scattering Measurement Using Multiple Reflection and the Time-of-Flight of Laser Light
Takashi Sumikawa, The University of Tokyo

P8-26 Laser scattering measurement of the electron density fluctuations in CHS
Yoshifumi Azuma, Tokyo Institute of Technology

P8-27 Laser Thomson Scattering Measurements in Helium Recombining Plasmas in Divertor/Edge Simulator MAP-II and its Comparison with Spectroscopy
Filippo Scotti, The University of Tokyo

P8-28 Collective Thomson scattering for alpha-particle diagnostic in burning plasmas
Takashi Kondoh, Japan Atomic Energy Agency

P8-29 Sensitivity study for the optimization of the viewing chord arrangement of the ITER poloidal polarimeter
Taiki Yamaguchi, Japan Atomic Energy Agency

P8-30 Bench testing of polarimeter with Si photo elastic modulator for short wavelength FIR laser
Tsuyoshi Akiyama, National Institute for Fusion Science

P8-31 Development of Short Wavelength Far-Infrared Lasers and Optical Elements for Plasma Diagnostics
Kazuya Nakayama, Chubu University

P8-32 Effect of pressure and magnetic field on parameters of plasma in a DC cylindrical magnetron sputtering device
Kiomars Yasserian, Plasma Physics Research center, Science and Research Branch,Islamic Azad University

P13-01 Electron Energy Distribution Functions in a Low Pressure Inductively Coupled CH4/H2 Plasma
Katsuyuki Okada, National Institute for Materials Science

P13-02 ECR heating and ECE diagnostic in W7-X stellarator: ray tracing simulations of non-thermal effects
Nikolai B. Marushchenko, Max-Planck-Institut fuer Plasma Physik, EURATOM Association

P13-03	Carbon redeposition under high-flux, low-energy ion irradiation effects on properties of tungsten films Liudvikas Pranevicius, Vytautas Magnus University, Lithuania
P13-04	An exact linear dispersion relation for CRM instability Kazuo Minami, Faculty of Engineering, Tokyo Denki University
P13-05	Mapping of flux quantities in the high beta heliotron plasmas Kiyomasa Y. Watanabe, National Inststitute for Fusion Science
P13-06	Development of the Web Interface for FIT Program Masahiko Emoto, NIFS
P13-07a	Physics of Radiative Collapse in the Large Helical Device Yuri Igitkhanov, Max-Planck-Institut fuer Plasmaphysik, IPP-EURATOM Ass.
P13-07b	Impurity Transport Studies on LHD Yuri igitkhanov, Max-Planck-Institut fuer Plasmaphysik, IPP-EURATOM Ass.
P13-07c	Stellarator Impurity STRAHL Code Development in NIFS Yuri igitkhanov, Max-Planck-Institut fuer Plasmaphysik, IPP-EURATOM Ass.

Poster Session 2 – Imaging (Categories 1-4, 6, 9-13)

P1-01 Somato-motor inhibitory processing in humans: a study with MEG and ERP
Hiroki Nakata, National Institute for Physiological Sciences

P1-02 Somatosensory mismatch responses using oddball paradigm; an MEG study
Kosuke Akatsuka, National Institute for Physiological Sciences

P1-03 Imaging mass spectrometry revealed abnormal distribution of phospholipids in colon cancer liver metastasis
Takahiro Hayasaka, Okazaki Institute for Integrative Bioscience

P2-01 Constrained Electron Beam Tomography for Identifying 3-Dimensional Movements and Twisting Mechanizm of Sperm Flagella of the Stag Beetle *(PROSOPOCOILUS INCLINATES)*
Masaru Irie, Waseda University

P2-02 Developments of split reporter proteins for biomolecular imaging
Masaki Takeuchi, Department of Molecular Structure, Institute for Molecular Science

P2-03 Direct Observation of Intracellular Materials Using a Phase Contrast Transmission Electron Microscope (TEM).
Koji Nitta, National Institutes of Natural Sciences, Okazaki Institute for Integrative Biosciences

P2-04 Structural Analysis of Non-Selective Cation Channel TRPV4 using a Phase-Contrast Transmission Electron Microscope
Hideki Shigematsu, National Institutes of Natural Sciences

P4-01 Imaging of tungsten impurity ejected from damaged material due to transient heat load
Shin Kajita, Nagoya University

P4-02 Near-field optical imaging of electric field and wavefunctions in metal nanoparticles
Hiromi Okamoto, Institute for Molecular Science

P4-03 Supported phospholipid bilayer membranes on SiO_2 and TiO_2 surfaces
Ryugo Tero, Institute for Molecular Science

P6-01 Charge transfer in collisions of proton with CH3 molecules
Hida Ken-nosuke, Foundation for Promotion of Material Science and Technology of Japan

P6-02 Fulcher-α spectra in the mixed hydrogen isotope plasma
Taiichi Shikama, School of Engineering, The University of Tokyo

P6-03 Analyses of visible images of the plasma periphery observed with tangentially viewing CCD cameras in the Large Helical Device
Mamoru Shoji, National Institute for Fusion Science

P6-04 A new Doppler shift spectroscopy for the measurement of neutral beam profile
Yuejiang Shi, Institute of Plasma Physics,Chinese Academy of Sciences

P6-05 Observation of Hydrogen and Cesium Spectra in a Negative Ion Source for a Neutral Beam Injector using a Multi-channel Spectrometer
Katsunori Ikeda, National Institute for Fusion Science

P6-06 A Multi-reflection Type Visible-laser Interferometer for High Density Plasma Measurements
Kunihiko Hattori, Department of Electrical Engineering, Graduate School of Engineering, Tohoku University

P6-07 Development of real-time measurement system of charge exchange recombination spectroscopy and its application to feedback control of ion temperature gradient in JT-60U
Shinji Kobayashi, Institute of Advanced Energy, Kyoto University

P6-08 Temperature Diagnostics for Field-Reversed Configuration Plasmas on the Pulsed High Density (PHD) Experiment
Hiroshi Gota, Plasma Dynamics Laboratory, University of Washington

P6-09 A simultaneous spectroscopic measurement for the global and edge fine structures of the ion temperature and plasma rotation profiles in the Compact Helical System
Shin Nishimura, National Institute for Fusion Science

P6-10 Simultaneous Measurement of Proton Ratio and Beam Divergence of Positive-ion-based Neutral Beam in the Large Helical Device
Kenichi Nagaoka, National Institute for Fusion Science

P6-11 Infrared Imaging Video Bolometer with a Double Layer Absorbing Foil
Igor Vitalevich Miroshnikov, Saint-Petersburg State Polytechnical University, Plasma Physics Department

P6-12 Two-dimensional measurement of inward neutral flux in LHD
Motoshi Goto, National Institute for Fusion Science

P6-13 Design of Impurity Influx Monitor (Divertor) for ITER
Hiroaki Ogawa, Japan Atomic Energy Agency

P6-14 2-d image diagnostic technique for edge turbulence using fast cameras
Nobuhiro Nishino, Hiroshima University

P6-15 Two-dimensional measurement of plasma dynamics with an ICCD fast camera based on HeI line intensity ratio method
Yamamoto Norimasa, EcoTopia Science Institute, Nagoya University

P6-16 High-speed visible imaging of central-cell plasmas in the GAMMA 10 tandem mirror
Yousuke Nakashima, Plasma Research Center, University of Tsukuba

P6-17 Behavior of Hydrogen Fueled by Pellet Injection in the GAMMA 10 Tandem Mirror
Yuusuke Kubota, Plasma Research Center, University of Tsukuba

P6-18 Measurements of Oxygen Ion Spectra for Estimation of Electric Field Profiles in Cylindrical Plasmas
Takayuki Kobayashi, Plasma Research Center, University of Tsukuba

P6-19 Study of Edge Plasma Characteristics at H-mode Transition in Heliotron J
Shinya Watanabe, graduate school of energy science, Kyoto university

P6-20 Spectroscopic measurements of emission spectra by using multi-channel UV/visible impurity monitor
Ken Matama, Plasma Research Center, University of Tsukuba

P6-21 Line analysis of EUV spectra from molybdenum and tungsten injected in LHD
Malay Bikas Chowdhuri, Graduate University for Advanced studies

P6-22 Fast XUV 16$\times$ 16 array hybrid module for plasma imaging applications
Andrey Alekseev, Troitsk Institutre for Innovation and Fusion Research

P6-23 Comparison of Three Types of Impurity Diagnostics on Reheat Mode Discharges in the Compact Helical System
Chihiro Suzuki, National Institute for Fusion Science

P6-24 Improvement of AXUV bolometric measurement system at a semi-tangential cross-section in LHD
Naoki Tamura, National Institute for Fusion Science

P6-25 Spectroscopic Study of Plasma Flow Generated by Magnetoplasma Compessor with Transparent Electrodes
Jagos Puric, Faculty of Physics University of Belgrade

P6-26 Application of a soft-X ray imaging system to the STE-2 RFP
Onchi Takumi, Kyoto Institute of Technology

P6-27 Development of a soft-X ray imaging system for MHD studies in an RFP plasma
Akio Sanpei, Kyoto Institute of Technology

P6-28 Soft X-ray measurement in IRE on the TST-2 tokamak
Keisuke Sasaki, Graduate School of Engineering Sciences, Kyushu Univ.

P6-29 Soft X-ray emission profile and mode structure during MHD events in the TST-2 spherical tokamak
Hiroshi Hiroshi tojo, Graduate School of Frontier Sciences, The University of Tokyo

P6-30 Soft and Ultra-Soft X-ray Detector Array Systems for Measurement of Edge MHD Modes in the Large Helical Device
Fumitake Watanabe, Department of Energy Engineering and Science, Nagoya University

P6-31 Runaway Electrons as a Diagnostic of Plasma Internal Magnetic Fluctuations
Yongzhen Zheng, Southwestern Institute of Physics,

P6-32 The Investigation of Major Disruption Based on Plasma Current Beat-wave Excitation in IR-T1 Tokamak
Masoud Rezvani, Plasma physics research center,islamic azad university

P6-33 Development of a High Resolution X-Ray Imaging Crystal Spectrometer for Measurement of Ion-Temperature and Rotation-Velocity Profiles in Fusion Energy Research Plasmas*
Kenneth Wayne Hill, Princeton University Plasma Physics Laboratory

P6-34 Measurements of iron K lines using a wide band and compact X-ray crystal spectrometer in LHD
Ikuya Sakurai, EcoTopia Science Institute, Nagoya University

P6-35 Transport study of medium-Z impurities by means of X-ray Pulse-Height Analyzer in LHD
Sadatsugu Muto, National Institute for Fusion Science

P6-36 Development of advanced X-ray Imaging Crystal Spectrometer utilizing a large-area proportional count for KSTAR
Sang gon Lee, National Fusion Research Center

P6-37 Investigation of a novel X-ray tube for the calibration of the X-ray crystal spectrometer in the KSTAR machine
Jun-gyo Bak, National Fusion Reserach Center

P6-38 A hard x-ray tomography system for the MST Reversed Field Pinch
Rob Oconnell, University of Wisconsin – Madison

P6-39 Current profile estimation in full LHCD plasmas using Hard X-ray measurement along the top and bottom identical line of sight on TRIAM-1M
Kazuaki Hanada, Research Institute for Applied MEchanics

P9-01 Measurement on spatial distribution of visible line spectra in LHD
Hisamichi Yamazaki, Department of Fusion Science, School of Physical Science, Graduate University for Advanced Studies

P9-02 Spatial variation of the foil parameters from in situ calibration of the JT-60U imaging bolometer foil
Homaira Parchamy, National Institute for Fusion Science

P9-03 Tracking and Visualization of Sharp Interfaces in a Three-dimensional Plasma Simulations
Caesar Ondlan Harahap, The Graduate University for Advanced Studies

P9-04 Nonstop Lose-less Data Acquisition and Storing Method for Plasma Motion Images
Hideya Nakanishi, National Institute for Fusion Science

P9-05 Acquisition of Data for Plasma Simulation by Automated Extraction of Terminology from Article Abstracts
Lukas Pichl, International Christian University

P10-01 2D tomographic imaging of the edge turbulence in RFX-mod
Gianluigi Serianni, Consorzio RFX, Associazione EURATOM-ENEA sulla fusione

P10-02 Tomographic reconstruction of emissivity profile from tangentially viewed images using pixel method
Santanu Banerjee, Institute for Plasma Research

P10-03 Two-dimensional Spectroscopic Measurement of Deuterium Emission in JT-60U Detached Divertor Plasmas
Fujimoto Kayoko, Japan Atomic Energy Agency

P10-04 Soft x-ray tomography in fusion plasmas: the Reversed Field Pinch case
Paolo Franz, Consorzio RFX

P10-05 Tomographic reconstruction of internal instability in a field-reversed configuration
Tomohiro Kiguchi, College of Science and Technology, Nihon University, Tokyo, Japan

P10-06 Quantitative evaluation of tomographic resolution by coded penumbral imaging
Shinya Nozaki, Information and Communication Systems Engineering, Okinawa National College of Technology

P10-07 Application of Tomographic imaging to multi-pixel bolometric measurements
Yi Liu, National Institute for Fusion Science

P10-08 Spherical Harmonics Decomposition in 3-D Vector Tomography
Alexander Leonidovich Balandin, Institute of System Dynamics and Control Theory of Russian Academy of Sciences

P10-09 Single Particle Analysis of Image Data Acquired by Zernike Phase Contrast Transmission Electron Microscope
Radostin Stoyanov Danev, Okazak Institute for Integrative Bioscience, National Institutes of Natural Sciences (NINS)

P11-01 Neutron Radiographic Imaging of Irradiated Fission-, Spallation- and Fusion-Materials
Masayoshi Tamaki, Graduate School of Engineering, Nagoya University

P11-02 Application of the Liquid-crystal-based tunable Lyot filter to the Optical Emission Imaging Plasma Spectrometry
Shinichiro Kado, High Temperature Plasma Center, The University of Tokyo

P11-03 Development of the monitoring system of plasma behavior using a CCD camera in the GAMMA 10 tandem mirror
Hirokazu Kawano, Plasma Research Center, University of Tsukuba

P11-04 Development of phosphor screen having ”gridded energy analyzer” for two- fluid nonneutral plasma experiments
Kohei Morita, Kyoto Institute of Technology, Department of Electronics

P12-01 Imaging challenges in long pulse nuclear fusion experiments
Ralf Koenig, Max-Planck-Institute for Plasma Physics

P12-02 Observation of toroidal asymmetric radiation in the Large Helical Device
Naoko Ashikawa, National Institute for Fusion Science

P12-03 Effects of face contour and features on occipitotemporal activity when viewing eye movement
Kensaku Miki, Department of Integrative Physiology, National Institute for Physiological Sciences

P12-04 Neural mechanism for processing of biological motion perception: An event-related potential study
Masahiro Hirai, Department of Integrative Physiology, National Institute for Physiological Science

P12-05 Centrifugal regulation of human cortical responses to a task-relevant somatosensory signal triggering voluntary movement: An MEG study.
Tetsuo Kida, Department of Integrative Physiology, National institute for Physiological Sciences

P12-06 The magnetoencephalographic neural activity related to the perception of apparent motion defined by various cues
Emi Tanaka, National Institute for Physiological Science

Plenary / Invited / Oral sessions

I1-1

Diffusion MRI

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MRI has made a great impact on the imaging research as well as clinical practice since its introduction. The most significant feature of MRI is the ability to obtain the image itself and the chemical or physical characteristics of the tissues. It depends upon the imaging sequences for MRI. In clinical situations, T1 and T2 weighted images as well as MR angiography is the standard sequences, and T2* EPI is utilized in functional MRI to investigate the cognitive neurosciences, which have a great success in the localizations and connections of various brain areas in the living human brain.

Diffusion is the phenomena of random motion (Brawnian motion). In order to visualize this phenomena by MRI, diffusion sequence was made by Denis Le Bihan, who had been working with us for one year and found the usefulness in functional brain imaging. Diffusion weighted images (DWI) were obtained routinely in the clinical examination for stroke patients to detect the very early phase of ischemic lesions in 1990s. This is a very sensitive image to find out the ischemic lesion as early as 30 min after ictus. DWI is also able to detect abnormalities in the cerebral cortex of Creitzfeldt-Jacob disease very specifically.

The most significant impact by DWI on neuroscience is the tracing of nerve fibers in the human brain. This is plausible on the fact that the fine water movement occurs through the nerve fibers as axonal flow. We can make the tracing images so-called “tractography” by using the data obtained by DWI, calculating the value of tensor in each voxels. On this images, we can see the fiber connections, such as optic radiation, pyramidal tract etc.

We recently found DWI as a tool of functional imaging. In 2002, Le Bihan reported the signal changes of the visual cortex in DWI by visual stimulation. Collaborating with him, we could find the more accurate signal changes in the visual cortex by photic stimulation, and compared the signal change data with BOLD signal, suggesting that DWI showed the more prompt response to visual stimuli than BOLD, therefore, we assume that diffusion functional MRI will be more fruitful if we can get the good signal to noise ratio.

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Direct and fast detection of neuronal activation in the human brain with diffusion MRI.

I1-2

Study of the Complex Physics of the Magnetic Reconnection Process in High Temperature Plasmas using a High Resolution Microwave Imaging System.

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High resolution (temporal and spatial) 2-D images of electron temperature fluctuations measured by a microwave imaging system [1] based on Electron Cyclotron Emission were employed to unfold unresolved physics phenomena such as the magnetic reconnection process and local heat transport of the fundamental Magneto-Hydro-Dynamic (MHD) instability (sawtooth oscillation; m=1 mode) in tokamak plasmas. Verification of theoretical models for the common phenomenology is greatly benefitial to the broader areas such as astro and solar physics. Up to now, the physics models for this problem are too complex to decipher the underlying physics with the conventional diagnostic tools. The experimentally measured 2-D images are directly compared to the expected 2-D patterns of the plasma pressure (or electron temperature) from prominent theoretical models developed for the m=1 mode (sawtooth oscillation) over the last three decades [2,3]. They are full reconnection, quasi-interchange, and ballooning mode models. These images were able to demonstrate that none of these models are fully consistent with the experimental observation and have provided a detailed process of the local magetic reconnection during the sawtooth crash.

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O1-3

On Imaging of Plasma Turbulence

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'Imaging' is composed of various processes in human recognition. In one of thoughts, the visualization of the subject is a central theme, but in the others, emphases are put upon the process of comparing the icon and knowledge with the models, to establish understanding. The fundamental issue in studying (thus in making the imaging of) the turbulence is to identify the nonlinear interactions among excited degrees of freedoms, and to extract a law. In plasma turbulence, turbulent fluctuations are composed of (nonlinear) collective modes and incoherent granulations. Collective modes are considered to interact through wave-wave (W-W) interactions and wave-particle (W-P) interactions. In the end, both of the nonlinear interactions must be measured and integrated into our understanding. Unfortunately, the measurement on the W-P interactions has been very limited so far, and experimental studies are more abundant for W-W interactions. The latter interactions are dominated by the three-wave coupling. Therefore, the analysis of the third order spectrum is a useful method to measure the nonlinear interactions in plasma turbulence. Quantitative studies of nonlinear interactions in plasma turbulence are now possible, as a result of the rapid progress of capabilities in data acquisitions and computations. We shall discuss the image of plasma turbulence, through interpretations of observations, which are given by the higher order spectral analysis. By employing the bipspectral method, magnitudes of interactions among excited modes are estimated and comparisons with theoretical modeling are performed. Interactions between microscopic turbulence and large-scale structures are also demonstrated, providing our understanding how global structures are generated by turbulence. This is a new step in establishing imaging of plasma turbulence.

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I2-1

Recent Progress on Analytical Image Reconstruction Methods for Tomography

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Image reconstruction from projections is a key step in tomographic imaging. In this paper, we provide a comprehensible review on recent progress on analytical image reconstruction methods. The paper mainly covers two types of image reconstruction problems in which significant progress has been achieved since 1990. The first problem we pick up is the region of interest (ROI) reconstruction from limited projection data, where our aim is to reconstruct a small portion of the object called the ROI from a set of line integrals less than the ordinary complete data set. In particular, we explain two image reconstruction methods (super-short-scan algorithms for fan-beam tomography and two-step Hilbert transform algorithms to enable exact reconstruction from truncated projections, developed by Noo and coworkers). The second problem we pick up is the cone-beam reconstruction, where our aim is to reconstruct a 3-D object from a set of cone-beam projections. We explain several key results on the cone-beam reconstruction (the Feldkamp algorithm for a circular source trajectory, Tuy's data sufficiency condition, Grangeat's algorithm based on the first derivative of 3-D Radon transform, cone-beam FBP algorithm by Defrise and Kudo, and Katsevich's algorithm). Due to the limited presentation time, we will not cover algebraic or iterative reconstruction methods.

I2-2

Present and Future of Computed Tomography Technology

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Cone Beam Computed Tomography (CBCT) is one of the most recent technological advancements in x-ray computed tomography. The state-of-the-art 64-slice scanners provide isotropic sub-millimeter spatial resolution, superior dose efficiency, large volumetric coverage, and markedly improved temporal resolution. These capabilities open doors to new clinical applications so that the entire human body can be scanned easily in a single breath-hold and a gated coronary artery imaging in 5 seconds.
In the past few years, significant efforts have been focused on increasing volume coverage and improving scan speed. Not long ago, 4-slice CT with one-second gantry rotation was considered a state-of-the-art scanner. Today, the coverage spec has increased 16 times and the scan speed more than tripled. This paper first discusses technical challenges that face the development of CBCT. These challenges include the detector design complexity, x-ray flux management, electrical and mechanical design difficulties, image reconstruction algorithms, dose, and information management. We then examine the new clinical applications that are enabled by the new technology, such as cardiac imaging, organ perfusion, triple-rule-out, and CT angiogram.
The second part of the presentation discusses more recent developments in CBCT technology. These include advanced dose-reduction techniques, the dual-source CT, advanced reconstruction algorithms that break the traditional noise vs. dose tradeoffs, and dual-energy CT for material decomposition. If the past 10 years of CT development is characterized by the “slice-war”, the CT technology today is truly at the cross-road where new developments are pointing at different directions.

I2-3

Optical coherence imaging for high resolution plasma spectroscopy

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We have recently obtained the first 2-d plasma Doppler spectroscopic images of transient, high-temperature plasma phenomena. Using compact polarization optical methods, quadrature images of the optical coherence of an isolated spectral line are multiplexed to four quadrants of a fast CCD camera. The simultaneously captured, but distinct images can be simply processed to unfold the plasma brightness, temperature and flow fields. This static system is a spatial-multiplex variant of previously reported electro-optically modulated, temporal-multiplex coherence imaging systems. It is based on a high throughput imaging polarization interferometer that employs crossed Wollaston prisms and appropriate image plane masks. Because the information is captured simultaneously, it is well-suited to high-spectral-resolution, high-throughput 2-d imaging of transient or rapidly changing spectroscopic scenes.

More generally, when the spectral information content of a given scene can be characterized by a small number of parameters (MSE, Zeeman effect, thermography, bremmstrahhlung, Thomson scattering), it is possible to construct high-throughput interferometers that directly target the desired information. For example, in the Doppler case, the visibility and phase of optical fringes at an optical delay close to the optical coherence length, vary sensitively to changes in plasma temperature and flow speed. When measuring relative line intensities (e.g. closely spaced isotope lines), the optical coherence varies most sensitively near the first zero of the beat pattern produced by the sum of the independent interferograms.

To demonstrate instrument performance we present recent results of static 4-quadrant Doppler coherence imaging on the H-1 heliac at the ANU. We also report coherence-based measurements of spectral line ratios and discuss the application of birefringent filters for Thomson scattering imaging of plasma electron temperature.

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I2-4

Ionospheric Tomography by Neural Network Collocation Method

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Computerized tomography (CT) is studied extensively in various fields to reconstruct material distributions from a dataset observed outside the region of interest. In the fields as medical applications where a large quantity of required observation data is obtained comparatively easily, high speed analysis methods with high precision are developed and practically used. In the cases of the physics experiments or outdoor observations, however, positions of observation equipments cannot be chosen arbitrarily and consequently the observation paths are not uniformly distributed and, often, the number of the projection paths is not sufficiently large. On the basis of the neural network collocation method we proposed the CT analysis method for a small qauantity of projection data and applied the method to reconstruction of the three dimensional electron density distribution of the ionospheric plasma from the TEC (Total Electron Content) data observed by the GPS system. The observed TEC value is the line integral of the electron density on the path between a sattelite and a receiver. In this CT image reconstruction problem there exist some difficult issues; (1) there are not sufficiently large number of simultaneously observed data, (2) the distribution of the projection paths is not uniform, (3) there are no paths around the horizontal direction. It is, therefore, rather difficult to apply the conventional CT analysis methods to this problem.
In this method the electron distribution of the ionospheric plasma is represented by a multilayer neural network. Training of the neural network is carried out by minimizing square of the difference between the observed TEC for a projection path and the line integral of the electron density represented by the neural network along the path. This line integral is calculated numerically from the output of the neural network at prescribed collocation points. For the success of the CT image reconstruction two additional techniques are important. First, absolute value of the electron density at one point within the region of interest is supplied by using the data observed by the ionosonde. Secondly, the input space should be discretized though the neural network can deal with continuous coordinates.
We first applied the method to a model problem produced from the GCPM (Global Core Plasma Model) based on the IRI (International Reference Ionosphere) and attained a satisfactory result. Then we applied it to a real data observed by the 40 GPS receivers located from Wakkanai to Okinawa with the ionosonde data at Kokubunji and attained successful results. The reconstructed maximum densities and the corresponding heights are confirmed to coincide with the observed data also at the three ionosonde sites other than Kokubunji.

I3-1

Advanced Microwave/Millimeter-Wave Imaging Technology

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Advances in millimeter wave technology have made possible millimeter wave imaging for advanced plasma diagnostics, radio astronomy, atmospheric radiometry, concealed weapon detection, all-weather aircraft landing, contraband goods detection, harbor navigation/surveillance in fog, highway traffic monitoring in fog, helicopter and automotive collision avoidance in fog, and environmental remote sensing data associated with weather, pollution, soil moisture, oil spill detection, and monitoring of forest fires, to name but a few. The primary focus of this talk will be on technology advances which have made advanced imaging and visualization of magnetohydrodynamic (MHD) fluctuations and microturbulence in fusion plasmas. Topics of particular focus include frequency selective surfaces, planar Schottky diode mixer arrays, electronically controlled beam shaping/steering arrays, and high power millimeter wave sources.

I3-2

Spectroscopy and Imaging by Laser Excited Terahertz Waves

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Up to very recently, terahertz (THz) electromagnetic waves (0.1 ~ 10 THz) have been an unexplored frequency region of electromagnetic waves. This electromagnetic wave region has become one of the most promising field by the recent development of the methods of THz generation by using femtosecond lasers.1)

The THz time-domain spectroscopy (THz-TDS) using the pulsed THz waves is very effective for characterizing various materials, i. e. semiconductors, superconductors, polymers, ferroelectrics, biomolecules, liquids, and gases.2) For example, the complex dielectric function associated with the solid state plasma in semiconductors can be measured without electrical contact, giving the density and mobility of carriers.3) The time evolution of the density and collision time of the discharge gas plasma has been measured by the THz-TDS using the same analysis with that for solid state plasmas.4)

The THz imaging systems have also been developed for diagnosis of various objects.5) In addition to the raster-scan type imaging systems, the real-time imaging system using the electro-optic crystal has been developed. Since the paper, ceramics, and plastics transmit the THz waves considerably, defects or objects in these materials can be visualized by the THz beams. For example, plastic bombs and illicit drugs in mails can be detected by the THz spectroscopy and imaging systems.6,7) The THz tomography is possible by measuring the waveforms of THz pulses reflected by the objects. The tomographic images of a tablet and nail are obtained. The THz tomographic imaging system will be also effective for diagnosis of fusion plasmas.8) The reflected pulse waveform carries information on the spatial distribution of plasma frequency or plasma density.

The THz specteroscopy and imaging will be used in industries in near future.

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I3-3

Evolution of Ultra-High-Speed CCD Imagers

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In 2001, a video camera operating at 1,000,000 fps (frames per second) was developed, mounting a custom CCD imager, the ISIS, the In-situ Storage Image Sensor. The ISIS was invented and designed by the authors[1]. Since then, various innovative technologies have been developed and applied to improve the performance of the sensor, such as sensitivity, pixel count, dynamic range, etc. The sensor, recently designed, will achieve very high sensitivity as well as the ultra-high frame rate. Thus, the sensor was named the PC-ISIS, the Photon-Counting ISIS. The ultra-high frame rate is realized by the ISIS structure, and the ultra-high sensitivity is supported by the combination of three technologies, backside illumination, cooling and the CCM, the Charge Carrier Multiplier. The CCM is a very efficient amplification technology specific to the CCD imagers, that amplifies image signals with the increasing S/N ratio. The PC-ISIS is being developed originally for application to the ultra-high-speed video microscope for biological observations, ”The Ultra-high-speed Bionanoscope”. Once it will be developed, it can be widely applied to high-speed imaging in the various scientific and engineering fields as well as bioscience.

Furthermore, various CCD imagers with much higher performance in one or two specified functions can be developed by utilizing the technological components introduced for development of the PC-ISIS. For example, if we allow a lower dynamic range than that of the PC-ISIS, it is possible to design an image sensor operating at 100 MHz.

In addition to development of the PC-ISIS, many other technologies have been proposed and developed to support the ultra-high-speed imaging with higher image quality. Among them are a butting technology for larger pixel count, the video trigger system for synchronization of the image capture to occurrence of the target event, the terraced image sensor with the performance far beyond that of the ISIS, etc.

In the first part of the paper, the structure and the performance of the ISIS developed in 2001 are briefly summarized. Then, those of the PC-ISIS are presented with detailed explanation of the technological components supporting the performance. Other technologies developed for ultra-high-speed imaging are also outlined.

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O3-4

Simulation Studies on Advanced Microwave Diagnostics and Related Technology

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Microwave diagnostics such as reflectometry are receiving growing attention in magnetic confinement fusion research. The detailed measurements on density profile and its fluctuations might be required in order to obtain the better understanding of plasma confinement physics. Especially, the new methods of microwave reflectometry such as ultrashort-pulse reflectometry and imaging reflectometry have been recently developed, and then we think that it is very important to demonstrate computationally the usefulness of these new diagnostic methods as well as these experiments. From such a reason, we wish to emphasize the importance of the development of microwave diagnostic simulator[1] and the related technology such as advanced beam former.

We here study the relativistic effects of plasma in micro- and millimeter-wave propagation. This study is very important in understanding burning plasma physics related to the ITER project. The most significant effect in wave propagation is the change of cutoff layer due to the relativistic electron mass modification[2]. In this case, the electron mass m_e is modified to $m_e(1+5/\mu)^{1/2}$, where $\mu = m_e c^2/T_e$, T_e being the electron temperature. Then, the change Δn of the cutoff density n_c is given by $\Delta n/n_c = (1+5/\mu)^{1/2}-1$ for the O-mode cutoff , and $\Delta n/n_c = [(1+5/\mu)^{1/2}-1]/(1-\omega_{ce}/\omega)$ for the upper X-mode cutoff. The shift in the cutoff density due to relativistic effects is more significant for X modes. By performing two-dimensional FDTD simulations on electromagnetic wave propagation, we show that the numerical result for the cutoff density change is in good agreement with the theoretical estimation. This relativistic change of the cutoff density might bring us a new possibility of measuring the electron temperature profile.

Finally, we discuss the possibility of a new type of beam former, which is composed of metallic wires and can be very flexibly constructed. This new beam former is applicable in the wide frequency range from microwave to light wave, and we report the wave transmission characteristics of this beam former.

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I4-1

High density plasma probing with pulse proton beams generated in ultra-intense laser plasma interactions

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A MeV proton beam generated in ultra-intense laser plasma interactions has advantages as a probe beam to measure the high-density and transient plasmas. The typical density of the beam is 10^{12}within a few psec, which is useful for high time resolution of the images. The ultra low emittance is also one of the advantages of this laser proton beam since the typical emittance is 0.004 mm*mrad, resulting a high spatial resolution. Measurements of strong and fine structured electrostatic field generated in laser produced plasmas has been demonstrated using this protons as a prove beam [1].
Other interesting points of this proton beam could be broad energy spectra. These broad energy spectra of the pulse proton beam enable us to prove the plasma with a chirped pulse beam. The difference of the energy in the broad energy spectra can prove the plasma at different times corresponding to the proton energy since the flight time from the proton source to the proved plasmas decrease with the proton energy. For example, a high-density plasma will be imaged with 3MeV and 5MeV proton beams at a relative timing of 130 psec and 100 psec, respectively, if the distance between the probed plasma and the proton source is 3 mm. This technique has been applied to measure a time evolution of a strong electrostatic field generated in a laser plasma with a time resolution of 40 psec [2].
Taking account of the energy density and low emittance of the proton beam, nuclear reaction of the proton beam with high-density plasma such as Li doped plasmas could be also a useful tool to prove the plasmas. In this paper, we will present these high density prove techniques with high temporal resolution using the ultra-intense short pulse laser created MeV proton beam.

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Advanced imaging applications on ITER

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ITER is designed as a superconducting Tokamak, with additional heating from neutral beams and ion-cyclotron resonance heating. The projected energy multiplication for D-T fuel is Q = 10, yielding fusion output of around 500 MW,

The ITER plasma will radiate strongly throughout the electromagnetic spectrum, as well as emitting ions, neutrals and neutrons. This radiation will be monitored with a wide range of diagnostic techniques, many based on radiation imaging, both for machine control and protection, and to measure physics parameters.

Due to the severe radiation environment, and the difficult access to views of the plasma, advances are required in many areas of imaging, including: a) infra-red thermography to monitor the temperature of vessels walls and divertor targets, b) bolometry of radiated power for machine protection and power balance, c) visible imaging and spectroscopy for protection and control, d) VUV imaging and spectroscopy of ions characteristic of the cooler outer and divertor plasmas, e) x-ray imaging and spectroscopy of the hot core plasma, and f) gamma-ray and neutron spectroscopic imaging of nuclear reactions.

I4-3

The diagnosis of fast ions in fusion plasmas by means of collective Thomson scattering (CTS)

H. Bindslev

I5-1

Optimizing Phase Contrast in TEM by the use of an electrostatic Boersch Phase Plate

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Recently phase-plate-mediated Phase Contrast TEM has gained new interest with the successful use of a simple carbon film as a phase shifting device [1]. However, for high resolution imaging an electrostatic phase plate as proposed already by Boersch in 1947 [2] seems more suitable as it uses an electric field to affect the electron wave and thus avoids the additional interaction of electrons with matter. In our design an electrostatic micro-lens is placed in the centre of the diffraction plane of the objective lens. It is driven as a very weak einzel lens, which changes the phase of the unscattered electron wave while minimally affecting the focus of the unscattered electrons. After the successful fabrication of the necessary electrostatic micro-lens [3] we have now tested different Boersch phase plate prototypes in a Zeiss-NTS SESAM II. As test specimens we used amorphous films of carbon and tungsten, imaged at high defocus to visualize the expected change in the phase contrast transfer function (CTF). When applying the appropriate potential we find a cosine-like CTF, demonstrating the 90 degrees phase shift between scattered and unscattered electrons necessary for optimized phase contrast.
To visualize the change of contrast in images, we then recorded images of the protein crystal catalase close to focus (negatively stained with UAc and also in cryo-EM/embedded in ice). In conventional defocus-based phase contrast such images have almost negligible contrast, whereas object contrast in images recorded with the electrostatic phase plate is greatly enhanced. However, such contrast is at present also affected by the support structures of the phase plate, which obstruct electrons in the diffraction plane. These obstructing structures lead to both, the elimination of the lowest spatial frequency components, and also to single-sideband imaging, which itself increases object contrast. Model calculations for ice embedded biological samples (ribosomes as weak phase objects) show, that such obstruction effects can be minimized, if the phase plate is placed in a magnified diffraction plane. This could be realized by the use of longer focal lengths objective lenses, or by simple magnification of the diffraction plane.

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I5-2

Cryo-EM study of dynein-microtubule interaction

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Recent biochemical studies of dynein, a minus-end-directed microtubule motor, have shown ATP-cycle dependant conformational changes. However, most experiments have been based on a 2D negative staining classification of dynein and were carried out in the absence of microtubules. The present study has carried out an analysis using cryo-EM and 3D reconstruction methods to investigate the structural interaction of dynein bound to microtubules.
Dynein is a minus-end-directed microtubule motor and uses ATP as the energy source to carry cargo along microtubules. Dynein is a large protein complex composed of two identical heavy chains (~500kDa), and several accessory chains. The heavy chain is responsible for its motor activity and consists of three structurally distinct domains: a globular head with ATPase activity, a cargo-binding tail, and a microtubule-binding stalk. The long slender tail, which is located in the N-terminus of the heavy-chain, binds to cargo and interacts with accessory chains. The globular head, which makes up 2/3rds of the heavy chain's C-terminal region, has a ring-like arrangement of seven sub-domains. The stalk protrudes from the head and is topped with a small globular domain that allows dynein to bind microtubules in an ATP-sensitive manner.
The current investigation has used single particle analysis, in combination with helical image analysis of microtubules. Recombinant cytoplasmic dynein containing 2/3rds of the heavy chain's C-terminal region was expressed in Dictyostelium. Images were collected using a CCD camera and (14.3) microtubules were selected manually according to their moire patterns. Approximately 300 microtubule filaments were analyzed. 1200 dynein particles, sparsely bound to microtubules, were selected. Images of microtubules were straightened and magnifications normalized. To select particles overlapped with microtubule density on images, the density from microtubules was computationally removed. The initial model was made from dynein decorated to the microtubule with sub-stoichiometric amount by reconstruction using microtubule helical symmetry. During the refinement process, cluster analysis was added to remove incorrect density of dynein. The reconstructed dynein microtubule complex showed a disk feature of dynein whose axis is orthogonal to the microtubule. Seven sub-domains of dynein were clearly visualized together with a short tail on top of the disk.
In this conference, details of the computational methods used will be discussed and a mechanism of how dynein interacts with microtubules in order to perform the power stoke will be proposed.

I5-3

Molecular Mechanisms of Swimming and Tumbling in Bacterial Motility

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The bacterial flagellum is made of a rotary motor and a long helical filament by means of which bacteria swim. The flagellar motor rotates at around 300 Hz and drives the rapid rotation of each flagellum to propel cell movements. The long helical filament, which is a tubular structure with a diameter of about 20 nm, is made of a single protein flagellin. The filament switches between left- and right-handed helical forms in response to the twisting force produced by reversal of the motor rotation, allowing bacteria to alternate their swimming pattern between run and tumble for taxis. The flagellum also has a short, highly curved segment called hook, which connects the motor and the helical propeller. Its bending flexibility makes it work as a nano-scale universal joint, while the filament is relatively more rigid to function as a propeller. The flagellum is constructed by self-assembly of proteins translocated from the cytoplasm through the narrow central channel to the distal end of the growing structure, where one of the three different cap complexes is attached to help efficient self-assembly of particular proteins that need to be assembled at each specific stage of assembly. Those flagellar proteins are exported from the cytoplasm into the central channel of the growing flagellum by the flagellar type III protein export apparatus, which consists of six membrane proteins and three soluble proteins. One of the proteins is FliI, an ATPase that provides energy for the export process. A few cytosolic chaperones are also involved to facilitate the export process. We have been trying to understand how those macromolecular nanomachines work by looking at their structures by X-ray crystallography, fiber diffraction and electron cryomicroscopy. X-ray crystallography is a powerful tool to visualize atomic structures of macromolecules. However, visualization of the structures at work is difficult because many proteins involved do not form stable complexes. For example, the flagellar basal body when isolated does not contain the stator unit and most of the type III export apparatus proteins. The subunit stoichiometry may also have distributions. Electron cryomicroscopy including single particle image analysis, helical image reconstruction and tomography would allow us to visualize those structures. I will describe how we have visualized some parts of the flagellar structure at nearly atomic resolution by complementary use of the two methods, what we have learned from them, and how we will proceed further to solve the flagellar structure as a whole for ultimate understanding of the mechanisms of its protein export, self-assembly, and rotation.

I5-4

Visualization of in vivo macromolecules in ice embedded whole cyanobacterial cells by Hilbert differential contrast transmission electron microscopy

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The ultimate goal of biological electron microscopy is to visualize molecular and cellular events in the living state with extremely high resolution. Currently, rapid freezing is considered to be the most reliable method to retain ultrastructure and molecular states of living cells for TEM observation. With the recently developed Hilbert differential contrast electron microscope (HDC TEM), it has become possible to visualize ultrastructures of rapidly frozen ice embedded whole cyanobacterial cells [1, 2].
The cells observed with HDC TEM were surrounded by a smooth cell wall and membrane and packed with numerous particles and filaments. Thylakoid membranes and carboxysomes with their detailed macromolecular structures were observed very clearly in the whole cells. Further, electron dense polyphosphate bodies were consistently found in rapidly growing cyanobacterial cells. Some of the filaments observed in the cells with HDC TEM appeared to be associated with the polyphosphate bodies. By applying various DNA staining techniques to visualize DNA at the ultrastructural level, DNA localization and its association with polyphosphate bodies were examined. Incorporation of BrdU in newly synthesized DNA conferred electron density and incorporation of Br was confirmed by electron spectroscopic imaging (ESI). HDC TEM combined with ESI opens up a new approach to visualize DNA fibrils in vivo at high resolution.

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I6-1

"Hinode"; A New Solar Observatory in Space

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The third Japanese solar observing satellite, Solar-B, was launched on 2006 Sep 23 from the Uchinoura Space Center of JAXA and it was named as "Hinode" (sunrise). Hinode carries three major telescopes: Solar Optical Telescope (SOT), X-ray Telescope (XRT), and Extreme-ultraviolet Imaging Spectrometer (EIS). These telescopes have been developed in an international collaboration of Japan, US, and UK for understanding the formation mechanism of the solar corona, dynamic events such as solar flares and coronal mass ejection, and magnetic fields on the sun.

SOT consists of a diffraction-limited optical telescope of 50cm aperture and a focal-plane package. The solar photosphere and chromosphere are observed with broad and narrow bandpass imagers for high-cadence imaging observations and with a spectropolarimeter for detailed vector magnetic-field observations. Continuous observations of small-scale magnetic fields on the sun, which is an important key to understand the energy input to the corona, have never been achieved before SOT/Hinode.

XRT is a grazing-incidence X-ray telescope that has a three-times better spatial resolution with 1 arcsec pixel sampling and an order of magnitude higher sensitivity for the low-temperature corona, compared with the performance of the soft X-ray telescope on-board Yohkoh (Solar-A). All coronal phenomena with temperatures of 1-30 MK are studied in detail with the best performance that has ever been achieved.

EIS is an imaging spectrometer working at an extreme-ultraviolet wavelength range. It observes solar plasmas of log T = 4.7-7.3. The line-profile spectroscopy with narrow slits and imaging observations with wide slits are possible. Motions of hot plasmas and the process of plasma heating to coronal temperatures are investigated with a high-sensitivity spectrometer.

All telescopes have started their commissioning activities after the successful launch of spacecraft. The performance of spacecraft that supports the diffraction-limited SOT observations and some of initial observations are briefly introduced.

I6-2

Solar Optical Telescope onboard Hinode for Diagnosing the Solar Magnetic fields

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The Solar Optical Telescope (SOT) onboard Hinode is a 50cm aperture telescope to provide high resolution images of the sun in visible lights (388 - 668nm)[1,2]. The focal plane package of SOT consists of the Broad-band Filter Imager which provides the highest spatial resolution images of the solar photosphere, the Narrow-band Filter Imager which takes 2-dimentional chromospheric images, Dopplergram and Magnetogram in high cadence, and the Spectropolarimeter which takes full Stokes line profiles to provide the highest precesion magnetic field maps of the photosphere. The most outstanding characteristics of SOT is its continuous and uniform data quality with the unprecedentedly high precesion at the spatial resolution of 0.2 - 0.3 arcsec.

The door of the telescope was opened on 25th Oct. with the successful SOT first light. At the time of writing this abstract, inflight calibration of instruments of SOT is still on-going, but the data already reveals the excellent performance of the SOT. Some of the initial results will be presented.

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I6-3

Multiplicity of Solar X-Ray Corona in Time and Space

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The solar corona is filled with high temperature plasma. However, it is still unclear how the corona is heated up. The X-Ray Telescope (XRT) on the Hinode satellite observes the solar corona, to reveal its heating mechanism by coordinated observations with the other telescopes on the Hinode satellite (Solar Optical Telescope;SOT and EUV Imaging Spectrometer;EIS). In the solar corona, many transient events occurr; solar flares, micro-flares, coronal mass ejections, X-ray jets and so on. It is believed that every events are related with magnetic activities. Therefore, the coordination between the coronal obsertvation by XRT and the photospheric magnetic observation by SOT is important.

XRT is a graizing incident telescope like the Soft X-ray Telescope (SXT) on the Yohkoh satellite. However, the spatial resolution is improved to 1 arcsec/pixel, which is about 3 times higher than the SXT. The observable temperature range is also improved, espesially for low temperature (1MK) plasmas. Therefore, the XRT can observe not only active events (>5MK) but also quiet coronal bases (1MK). The XRT has the capability of the temperature diagnostics. It is hoped that the XRT observes fine scale temperature structures in the solar corona.

I6-4

Emission Line Imaging Spectroscopy for Diagnosing of Solar Outer Atmospheres

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The Extreme Ultraviolet Imaging Spectrometer (EUV) [1,2] on board the Japanese Sun Observing Satellite "Hinode" (launch date: 23-Sep-06) accommodates the multilayer coated mirror and concave grating with back-illuminated CCDs for detectors, and realizes the highest sensitivity ever achieved in the two EUV wavelengths, i.e. 17 - 21 nm and 25 - 29 nm. Thanks to the normal incidence optics, the spectrograph geometry and grating ruling were optimized to obtain excellent imaging capability.

The scientific goals of the instruments on board are: a) to identify the mechanisms responsible for heating the corona in active regions and the quiet Sun, b) to establish the mechanisms that give rise to transient phenomena, such as flares and coronal mass ejections, and c) to investigate the processes responsible for energy transfer from the photosphere to the corona. The instrument EIS will be able to provide the detailed diagnostic information on solar corona and transition region.

After opening of the instrument doors, the first light of EIS took place successfully on 28-Oct-06. At the time of writing this abstract, the in-flight calibrations and testings are still in operation, but a glimpse of these data reveals the expected performance of the instrument in orbit. Some of these initial results will be presented.

Further in collaboration with NIFS, a new tool of time-dependent collisonal-radiative model will be developed to analyse the data taken by this EIS instrument, and to diagnose temperatures and densities of those plasmas in the outer atmospheres of the Sun. Possibility of getting the atomic data required for these analyses is also in consideration.

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I7-1

Heavy Ion Beam Probe, Present status and future development

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Heavy ion beam probe was unique and powerful diagnostics, since it is a local and non-perturbed measurement of plasma potential. HIBP is the ideal diagnostics for the detection of zonal flow as the non-linear interaction of drift-wave turbulence, since the sensitivity of small zonal flow as slow as ion diamagnetic drift velocity can be detected with high signal/noise ratio. It can be a Langmuire probe in the hot plasma core. We wish to report the recent results of zonal flow study in JIPPT-IIU tokamak and desirable development and modifications for future study. It also may be possible to detect plasma current profile in the tokamak plasma. The potential measurement of HIBP depends on the total energy conservation law in the electrostatic and magnetic field, while we may be able to the magnetic flux function, RAφ at the ionization point (sample volume) through the by the angular canonical conservation law. We installed the several detectors to measure the toroidal deflection of the beam and RAφ and we wish to report the calucations and results. The most serious problem of the HIBP when it is installed upon devices larger than JIPPT-IIU tokamak, is the beam attenuation by the plasma electron and shortness of penetration depth of the primary beam. In JIPPT-IIU case, the highest average density for potential turbulence study is about 3x1013/cm3 for Tl (thallium) beam. When we changed the Thallium beam to Cs, Rb, K and Na, the toroidal field matched to the beam, steadily goes down, and the penetration depth, however, grows steadily larger with no
penetration problem in Na case. We wish to report these results. The tandem accelerator has another possibility for the choice of the beam with good penetration. If the Al- beam is accelerated to the central gas chamber of the tandem accelerator with Va voltage, it may be highly ionized to Al+3 in the gas chamber and got the final energy of 4 Va. The ionization energy of the Al+3 is more 120 eV, compared to about 6.1 eV of Tl, the penetration depth may be so large and applicable to the large tokamak like JT-60U. We wish to report these calculations.

I7-2

Plasma Turbulence Imaging via Beam Emission Spectroscopy on the DIII-D Tokamak

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Plasma turbulence plays a critical role in energy, particle and momentum confinement in magnetically-confined fusion plasmas. Beam Emission Spectroscopy (BES), a high-sensitivity, good spatial resolution imaging diagnostic system, has been deployed and recently upgraded and expanded at the DIII-D tokamak to better understand such turbulence. The currently deployed system images density fluctuations over an approximately 5 x 7 cm region at the plasma mid-plane (radially scannable over $0.2 < r/a \leq 1$) with a 5 x 6 (radial x poloidal) grid of rectangular detection channels, at one microsecond time resolution. BES observes collisionally-induced, Doppler-shifted D_α fluorescence (λ = 652-656 nm) of a high-energy (75 keV) injected deuterium neutral beam. Alignment of the sightline of high-throughput viewing optics and the local magnetic field at the beam-sightline intersection provides good spatial resolution. The diagnostic wavenumber sensitivity is approximately $k_\perp < 2.5\ \mathrm{cm}^{-1}$, calculated via consideration of optical alignment and collimation, neutral beam dimensions, and finite lifetime effects of excited beam atoms. This resolution allows measurement of long-wavelength ($k_\perp \rho_i < 1$) fluctuations associated with plasma ion turbulence (e.g., ion temperature gradient and trapped-electron modes).
The recent upgrade includes expanded fiber optics bundles, custom-designed high-transmission, sharp-edge interference filters, ultra fast collection optics, and larger photodiode detectors that provide nearly an order of magnitude increase in sensitivity relative to an earlier generation BES system. A Linux-based data acquisition system (D-tAcq Solutions) provides simultaneous sampling of up to four megasamples per channel, or a 4.2 second continuous time record. The high sensitivity allows visualization of turbulence at normalized density fluctuation amplitudes of $\delta n(t)/n_o < 1\%$, typical of fluctuation levels in the core of low and high-confinement plasmas. The imaging array allows for sampling over 2-3 turbulent eddy scale lengths which captures the essential dynamics of eddy evolution, interaction and shearing. The imaging data allows for detailed study of poloidal flow and fluctuations therein resulting from such critical phenomenon as zonal flows. Examples of measured turbulence characteristics and movies (over $0.4 < r/a < 1.0$) will be presented.

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O7-3

Development of Polarization Interferometer Based on Fourier Transform Spectroscopy for Thomson Scattering Diagnostics

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The Thomson scattering method is one of the standard diagnostic techniques for the measurement of local electron temperature T_e and density n_e. Usually a grating spectrometer or filter polychromator is used to analyze the scattered spectrum to obtain information on the electron temperature and density. Though these are established methods, there are some disadvantages such as small throughput (especially, in the case of grating spectrometer) or the necessity of relative calibration between wavelength channels. Recently, the use of a polarization interferometer based on Fourier transform spectroscopy for Thomson scattering diagnostics has been proposed [1]. This method can alleviate some of the disadvantages noted above. Furthermore, this method delivers a simple and compact system. For thermal electrons, the optical coherence of the Thomson scattered light at an appropriately chosen optical path delay, is a unique function of T_e and n_e. The detection system utilizes a single bandpass filter combined with imaging optics and dual detectors to simultaneously observe both dark and bright scattered light interference fringes. The normalized intensity difference between the bright and dark interference fringes gives a direct measure of T_e, even for strongly blue shifted high temperature spectra. This paper describes the design and development plan for the wide field-of-view high transparency birefringent filter (polarization interferometer). For the first step, proof-of-principle tests will be carried out in TPE-RX reversed-field pinch device. The target T_e range is 100-1000 eV, target n_e range is 5×10^{18} - 5×10^{19}m^{-3}. In the second step, time evolution of T_e and n_e profiles having 20 spatial points will be measured in JT-60U tokamak using 50-Hz YAG laser system[2]. The target T_e range of the second step is considered up to 40 keV.

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O7-4

Advanced Laser Diagnostics for Electron Density Measurements

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Measurements of the refractive index of the plasma by using electromagnetic waves are a well-established tool for measuring electron density profiles in high temperature plasmas. In the LHD, a 13-channel far infrared laser interferometer has been constructed and routinely operated for the precise measurements of the electron density profile almost every shot except in the case of a high-density plasma produced by an ice pellet injection. When a large sized pellet is injected into the plasma steep density gradient is formed, which sometimes causes the fringe jumps on the density traces measured by fringe counters. In order to overcome this difficulty there are sevral methods, which are classified into two categories, the interferometry and the polarimetry.
In the first category, we need to develop short wavelength laser diagnostics to avoid the beam bending effect. However, it is necessary to equip a second wavelength interferometer to compensate mechanical vibrations of the optical components. In the LHD, a CO2 laser imaging interferometer has been developed for detailed profile measurements of density and density fluctuation. For the sake of vibration compensation a 1.06-μm YAG laser interferometer is employed. As like this, the conventional two color interferometer system is composed of two independent laser interferometers. Therefore, the fringe shift caused by the mechanical vibrations couldn't be cancel out completely. A newly developed two color laser interferometer[1] can overcome this difficulty. The laser source is a optically pumped CH3OD laser, which oscillates simultaneously at 57.2 and 47.6 μm. Some excellent features of the system are as follows:(i) the wavelength of 57.2 μm is considered to be optimum value to avoid refractive effects in high density operation of LHD and in future fusion devices, (ii) the optical components can be optimized at both frequencies, (iii) an additional laser instrument is not needed to compensate the fringe shift due to mechanical vibrations, (iv) both laser beams pass the same optical path in the interferometer without any optical path difference, and (v) one detector simultaneously detects the beat signals of both laser lines.
In the second category, polarimetry, the Faraday rotation and the Cotton-Mouton effect, can be considered to be robust measurements of the line integrated electron density, since the rotation angle is less than 2π radians by optimizing a laser wavelength for a target plasma. On CHS a Cotton-Mouton polarimeter with a 337-μm HCN laser was developed in order to see the accuracy and limitation of the meter. A CO2 laser densitometer[2] measuring the Faraday rotation angle was developed for the long-pulse operations of LHD. The values of these polarimeters depend on both the density and the magnetic field strength. In the helical system the confining magnetic field can be computed for low beta plasmas and then the density information can be derived. Details of each diagnostics and sample results will be presented in this conference.

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I8-1

MRI technologies in recent human brain mapping

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Magnetic resonance imaging (MRI) is a tool that allows us to investigate human brain activity non-invasively. What can we do with it now? The research center I belong to is home to about sixty faculty members from various backgrounds to develop new imaging technologies, which will be applied to biologically and medically important questions. In my talk, I will describe some of technologies developed here, and then their applications. First, I will introduce brain images in excellent spatial resolutions taken from 7T magnetic field, and whole brain diffusion tensor imaging. Next, I will show interictal spike localization in combination of magnetoencephalogram (MEG) and MRI. Finally, I will talk about our recent neuroscientific finding in symmetry perception in human and monkey functional MRI.

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The author is an ERATO Shimojo Implicit Brain Function Project Collaborative Researcher.

I8-2

Cross-modal integration and plasticity revealed by functional magnetic resonance imaging

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Recent advances in functional neuroimaging and electrophysiological techniques are quite rapid, allowing human physiology to be investigated in ways that have previously been impossible. The brain is a dynamically changing structure. Braille reading by the blind recruits the visual cortex. The sign language activated the auditory cortex of the deaf. The cross-modal plasticity may be caused either by sensory deprivation or by long-term training. To evaluate the long term learning effect on the cross-modal plasticity, we conducted functional magnetic resonance imaging (fMRI) studies. First, normally-sighted participants who had undergone long-term training on the tactile shape discrimination of two dimensional Mah-Jong tiles were recruited. When participants performed tactile discrimination of Mah-Jong tiles, the left lateral occipital cortex (LOC) and V1 of the well-trained subjects were activated. In the naive subjects, the LOC was activated whereas V1 was deactivated. Both the LOC and V1 of the well-trained subjects were activated by Braille tactile discrimination tasks. The activation of V1 may be due to cross-modal plasticity resulting from long-term training. Second, we investigated "key-touch reading" by which well trained pianists were able to identify the familiar music whereas less trained subjects were not. The left association auditory cortex of the well trained subjects was equally activated by observation of familiar music, unfamiliar music, and random sequences. As the naive and less trained groups did not show activation of the left PT during any of the tasks, PT activation reflects a long-term learned process. These studies showed that long-term learning dynamically modify the brain organization for the multisensory integration.

O8-3

Cortical Networks for Visual Self-Recognition

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The ability to recognize one's own visual image has been studied in human infants and animals, having a particular interest in its relationship with self-awareness and the concept of self. An infant usually starts to show evidence of self-recognition in a mirror in the second year of life. Except for chimpanzees and orangutans, no animals have demonstrated this ability even with extended periods of exposure to a mirror. These observations suggest that the ability of visual self-recognition requires a special cognitive mechanism.

Evidence from cognitive neuroscience research suggests that the self-specific process during visual self-recognition is likely to involve multiple independent processes sustained by discrete brain mechanisms. In fact, split brain patients recognize their own face in either hemisphere, and two hemispheres appear to have different sensitivities to one's own face and familiar faces. However, hemispheric dominancy in self-recognition has been a matter of controversy.

A recent fMRI study demonstrated specific involvement of the left ventral occipitotemporal cortex and the right parietal and frontal cortices in visual self-recognition [1]. Evidence of distinct roles of these regions in visual self-recognition was provided by the results of a subsequent fMRI study; sensitivity to self-image was different across three regions depending on the image attributes and subjects [2]. Taken together developmental and sociobehavioral views of visual self-recognition and previous findings on these regions, it has been speculated that the left ventral occipitotemporal cortex processes one's own face as a symbol, and the right parietal and frontal cortices play roles in visuo-spatial and conceptual self-representations, respectively.

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O8-4

Neuroimaging Study of the Human Amygdala
-Toward an Understanding of Emotional and Stress Responses-

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The amygdala plays a critical role in the neural system that is involved in emotional responses and conditioned fear. Dysfunction of this system is thought to be a cause of several neuropsychiatric disorders (e.g., schizophrenia, depression, and anxiety disorder). A neuroimaging study using functional magnetic resonance imaging provides a unique opportunity for noninvasive investigation of the human amygdala. We studied activity of this structure in normal young subjects, normal old subjects, and patients with schizophrenia using face recognition task. Our results showed that the bilateral amygdalae were significantly activated by the presentation of face stimuli, and negative face activated the amygdala to a greater extent as compared with neutral face. The amygdala also responded to the face that was shown implicitly. These observations indicate that the amygdala is extremely sensitive to face stimuli that have a biological value for humans. Activation of the amygdala was significantly lower in the old than in the young subjects, while schizophrenic patients showed enhanced activity in the amygdala. Single nucleotide polymorphism in the regulatory region of the serotonin type 3 receptor gene had significant modulation effects on the amygdaloid activity in normal subjects. The results indicate that there is a substantial difference in the amygdala activity among normal individuals. The variation in the amygdala responses that is explained by the genetic factors may be related to the variation in the susceptibility for socio-psychological stress. Thus, studies of the human amygdala would greatly contribute to elucidating the neural system that determines emotional and stress responses. To clarify the relevance of neural dysfunction and neuropsychiatric disorders, further studies using physiological, genetic, and hormonal approaches are essential.

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I9-1

Tangential SX imaging for visualization of fluctuations in toroidal plasmas

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In magnetically confined fusion devices, the plasma is confined by the nested magnetic surfaces. In order to realize economical fusion reactors, reduction of the strength of the magnetic field is required. However, when the ratio of the plasma pressure to the magnetic pressure decreases, various kinds of instabilities evolve. Among them, magnetohydrodynamics (MHD) instabilities, by which the plasma is deformed macroscopically, are in concern. Especially, non-linear evolution of them is fairly complicated; further study for the understanding of the non-linear nature and its relation to the transport is needed. Since the perturbations tend to have the equal phase along the field lines, the tangential view, which is almost parallel to the field lines, give a good opportunity to visualize the 2D structure. We have been developing a tangentially viewing soft X-ray camera system[1]. This system is a pinhole camera having a fast framing video camera equipped with scintillator screen for the soft X-ray detection. It can record tangential image with a framing rate up to 20 kHz. We will discuss the various kind of MHD phenomena observed by this camera. Future improvements to study the fluctuations with higher mode number will be also discussed.

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O9-2

Monochromatic x-ray imaging and spectroscopy with spatial resolution for ICF experiments

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The success of the laser fusion program is critically dependent on our ability to simulate the target performance. We have to rely upon simulations to predict whether or not the target irradiated on a large-scale facility will actually ignite. Therefore, while the large-scale facilities for Inertial Confinement Fusion (ICF) like NIF or LMJ are being constructed, smaller facilities like NRL Nike are used to keep testing and improving the reliability of the codes. They should be fully validated and benchmarked vs. experiment in a single-mode regime. A key component, which made these test experiments possible, is our new powerful diagnostic technique, monochromatic x-ray imaging coupled either to a streak or framing camera. Here we report on our continued development of the x-ray plasma diagnostics based on spherically curved crystals and bent Bragg-Fresnel lenses. The diagnostics are complimentary to each other and include x-ray spectroscopy with 1D spatial resolution and 2D monochromatic self-imaging and backlighting. The system is mostly used, but not limited to the medium range (2 keV) diagnostics of the targets ablatively accelerated by the NRL Nike KrF laser. An enhancement of this technique to the higher (up to 8 keV) and lower (0.6 keV) x-ray energies will be reported. A progress in high energy backlighting and self-imaging has been made in cooperation with LULI, France, LLNL, USA and RAL, UK.

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O9-3

X-ray spectroscopic diagnostics for laser-imploded core plasmas with high spatial and temporal resolutions

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For the study of energy transfer and deposition in fast igniter plasma [1], x-ray spectroscopy is an important method to obtain temperature and density profiles of the plasma given as a function of time and space. X-ray shadowgraphy is a standard method to investigate hydrodynamic behavior of laser-driven implosion and density profiles. To generate a blight x-ray source efficiently, laser-driven underdense targets have been suggested [2]: the laser deposits its energy volumetrically so that x-ray emitting ions are exited supersonically and power loss via plasma expansion is diminished. We have made experiments on x-ray generation using low-density, Ti-doped SiO_2 aerogel (6 atom% Ti) targets and GEKKO XII blue laser. Conversion efficiency of 2.3% into Ti-K shell radiation was attained and a propagation velocity of 10^8 cm/s for the ionization front was observed with an x-ray streak camera, which is ten times faster than the estimated sound velocity for $n_i = 10^{19}$ cm^{-3} and $T_e = 1$ keV. The latter value was confirmed with the observed x-ray spectra.X-ray spectroscopic observation for self-emitted radiation from the imploded core plasma is also an important diagnostic method. A novel scheme, consisting of a monochromatic x-ray imager [3] and a sampling streak camera [4], has been suggested to obtain time- and space-resolved temperature profiles of the fast igniter plasma. We carried out implosion experiments using Cl-doped plastic shell targets and the x-ray monochromatic sampling camera on the GEKKO XII laser in order to demonstrate the feasibility of this scheme. Details of the experiments and analysis will be discussed.

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O9-4

Research and Development of Imaging Bolometers

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An overview of the research and development of imaging bolometers giving a perspective on the applicability of this diagnostic to a fusion reactor is presented. Traditionally the total power lost from a high temperature, magnetically confined plasma through radiation and neutral particles has been measured using one dimensional arrays of resistive bolometers which utilize the electrical signal resulting from the temperature dependent resistance of a metal grid to measure the change in the temperature of the plasma radiation absorbing foil. The large number of signal wires associated with these resistive bolometers poses hazards not only at the vacuum interface, but also in the loss of electrical contacts that has been observed in the presence of fusion reactor levels of neutron flux [1]. Infrared imaging video bolometers (IRVB) [2], on the other hand, use the infrared radiation from the absorbing metal foil to transfer the signal through the vacuum interface and out from behind a neutron shield. In that sense they represent a reactor relevant alternative to the resistive bolometer which can provide hundreds of channels of bolometric signal in an image of the plasma radiation. Recently a prototype IRVB [3,4] has been deployed on the JT-60U tokamak which demonstrates the ability of this diagnostic to operate in a reactor environment. Video of the plasma radiation from the imaging bolometer on JT-60U will be shown along with plans for an upgrade of this diagnostic to better demonstrate its reactor relevance. In addition, recent work related to the IRVB in calibration, tomography, new detector foil development and applications to other fusion devices will be briefly reviewed.

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I10-1

Farewell cover slip: Light-sheet based microscopy (SPIM) fosters a modern approach to three-dimensional cell biology

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Models relying on “Petri-dish based” 2D cellular assays seem to be inadequate in predicting the behaviour of cells in tissues. They have often failed to provide clinically relevant infor-mation. This suggests that some essential cellular parameters are not captured by 2D assays. Certainly, one missing link coupling individual cells to a tissue’s function is the cellular con-text. In a 2D culture, cells are grown under conditions poorly reproducing the three-dimensional architecture, biochemical specificity, and cell-cell communication mechanisms of tissues. On the other hand, three-dimensional cell biology has shown that gels mimicking the extra-cellular matrix induce cells to reproduce aspects of their native function in tissues. We suggest that a combination of three-dimensional sample preparation and dynamic three-dimensional observation, that we call 3D2 (3D squared) improves the repeatability, the inter-nal consistency, and the physiological relevance of cell-based assays, fostering cell biology to become a quantitative science. By three-dimensional we refer to experimental conditions that essentially avoid hard and flat surfaces and hence favour less constrained physiological sam-ple dynamics [1]. We suggest that light-sheet-based microscopes are particularly well suited for studies of sensitive three-dimensional biological systems. The application of such in-struments can be illustrated with examples from the biophysics of microtubule dynamics and the distinctly different behaviour of three-dimensional cell cultures. A new implementation of the theta principle [2] takes advantage of parallel recording. This high-resolution light mi-croscope [3] has been developed for the modern life sciences. It is designed to generate im-ages of large samples (embryos, three-dimensional cell cultures) down to the sub-cellular level. The fundamental principle of EMBL’s Single Plane Illumination Microscope (SPIM) is the detection of fluorescence light perpendicular to the illumination axis. The illumination system provides the excitation light along the side of an object and hence excites fluoropho-res within an entire plane. The illuminating light sheet overlaps with the focal plane of a de-tection system that consists of a long working distance lens and a high-performance camera. SPIMaging provides optical sectioning directly. Photo-bleaching outside the thin volume of interest is completely avoided. The photo-toxicity of the illumination process is thus dra-matically reduced. Since a SPIM performs well with long working distance lenses and has a good penetration depth, millimetre-sized specimens can be observed in their entirety and as a function of time. To further increase the resolution and the information content of a data stack, rotation of the specimen adapts the excitation and detection axes to the sample. Parts of the sample that would otherwise be hidden or obscured become accessible. Data stacks recorded along different angles can be combined in post-processing steps to yield high-resolution images [4, 5]. The three-dimensional resolution is then dominated by the lateral resolution and becomes isotropic, i.e. identical, along all directions. Since the SPIMaging process provides for an excellent signal to noise ratio deconvolution and many other images processing procedures work extremely well [6]. During the past years various different spe-cies (mice, zebra fish, medaka, drosophila, yeast, …) were observed with our new micro-scopes.

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I10-2

Imaging of cell functions using by bioluminescence probes

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In the post genome era, molecular imaging is an essential approach to understanding the physiological system of the whole animal. The fact that bioluminescent probes based on luciferase technology utilize both natural and quantitative light energy in comparison with fluorescent probes such as GFP has resulted in their ability to visualize the molecular diversity of genes and proteins in living cells. We have created new luciferase technologies based on the novel bioluminescence system. In this presentation, I introduce our work as an example: Using beetle luciferases that emit various colors with a luciferin, we developed a revolutionary tricolor reporter in vitro assay system in which three gene expressions are monitored simultaneously using green-, orange- and red-emitting beetle luciferases. We used this novel system to analyze biological clock mechanisms that are generated by the extremely complicated transcription-translation feedback loop of clock genes, and successfully monitored simultaneously three gene transcriptions in the living cells. To further verify the applicability of this system, we used it in the development of tools for monitoring biological events in a single living cell. With the combination of the cooled CCD camera, we can visualize the motion of organelles in the single living cell for several days. This system could be utilized for detailed analysis in the new fields of transcriptome and promoterome, as well as in pharmacology or toxicology for the screening of new drugs or the detection of harmful chemicals.

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I10-3

In vivo Functional Imaging of Neural Cell and Secretory Gland Cell by Near-infrared Ultra-short Pulse Laser Light

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A molecule can transit with an extremely low probability from the ground state to the first electronically-excited one by simultaneous absorption of multiple photons. Such process is called as multi-photon excitation process. A new optical microscopy based on such multi-photon excitation process (“two-photon microscopy”) has been used widely in biological and medical sciences, because two-photon microscopy can visualize living cells in near intact states for a long time within deeper layers of organs. Such extremely low probability of two-photon excitation causes a property that pigments are excited and fluorescence is generated only at the focal point of the objective lens. This is because it is at the focal point where the laser photon density is maximized. Recently, we have recently succeeded in observing intact neurons deeper than 0.9 mm from the surface of the brain cortex in an anesthetized mouse. In the same preparation, we can determine morphologically dendritic spines and axon terminals, suggesting that their long-term changes can be chased in a living mouse. By another attractive property of two-photon microscopy, multicolor excitation capability, we have established a less-invasive imaging method for quantifying intracellular Ca^{2+}, and simultaneously visualizing fluid transports and a single episode of fusion pore opening during exocytosis[1-3]. In pancreatic acinar cells, we have found a sequential compound exocyotsis for the first time. Sequential compound exocyotsis has been found in many kinds of secretory glands including salivary glands. Further exploration revealed dynamics and physiological roles of actin cytoskeleton[4], fusion-pores, and SNARE proteins. Furthermore, we have succeeded in visualizing calcium-dependent water and electrolyte transport in nasal mucosal epithelial and salivary glands, and these may be used as an assay system for allergic rhinitis. As discussed above, this extremely rare quantum mechanical process results in extremely localized excitation ($< 10^{-15}$ *L*). By applying such localized two-photon excitation for photolysis of caged Ca^{2+} compund, we have achieved functional mapping of ion channels involved in water and electrolyte transport in pancreatic acinar cells. Because fluid transport is a general function of the exocrine gland, this technique may be applicable to various physiological and pathological studies. Two-photon microscopy will therefore advance the researches on mechanisms of exocytosis and fluid secretion in secretory cells in intact glands *in vivo*.

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I10-4

Symmetry break in developmentmental biology: Left-right determination.

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Human body is highly asymmetric in organ arrangement along left-right axis regardless of superficial symmetry. Certain relationship between this asymmetry (L-R asymmetry) and cilia, small hairs of micrometer length protruding from cells, had been suggested for decades but the actual mechanism had remained unknown.

We found that cilia on a patch on the surface of mouse early embryo, called “the node”, move in clockwise manner and generate fluid flow from the right to the left, named “nodal flow”. In a mutant strain we produced, lack of the cilia and randomization of L-R asymmetry coincided [1]. Thus we developed a device to culture mouse embryos under artificially reversed nodal flow to examine its significance. This device effectively reversed their L-R asymmetry [2].

Then we further approached to a question why sum of clockwise rotations by the cilia can produce leftward flow rather than a big vortex. We found that the rotations have actually posterior tilt by intensive observations of the embryos, and such tilt can produce leftward flow by mechanical fluid model experiments [3]. Overall, our studies addressed the earliest step of L-R asymmetry determination in mammalian development, in other words, expansion of molecular chirality to the body level.

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O11-1

Infrared magneto-optical imaging on an organic conductor by means of synchrotron radiation

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Infrared (IR) and far-infrared (terahertz, THz) spectroscopy is a powerful tool to investigate chemical bonding of organic materials and electrodynamics of solids. The experiments are usually performed by using commercial FTIR spectrometers. However, the performance (the spatial resolution, wavenumber range and so on) is poor. High brilliant synchrotron radiation (SR) in the IR–THz region is a suitable light source to break the experimental limit of the conventional systemsand to produce new measurement methodology.
Up to now, we have constructed two IR beamlines in Japan; one is BL43IR at SPring-8 and the other BL6B at UVSOR-II, Institute for Molecular Science. The former is used for a high spatial resolution spectroscopy of materials mainly in the mid-IR region. On the other hand, the latter gives the highest photon flux from SR in the world to cover down to the sub-THz region. Using these properties, we have performed some advanced spectroscopies in the IR–THz region. In this talk, we present the infrared magneto-optical imaging on an organic conductor.
The 50-% deuterated &kappa-$(ET)_2Cu[N(CN)_2]Br$ in fast cooling conditions, which is just on the Mott boundary, indicates a superconductor (SC) - insulator (I) transition due to a magnetic field. The origin has been believed to be the phase separation of SC and I phases induced by a magnetic field but no direct observation has been performed. Then the magnetic field-induced SC-I transition was observed using the IRMO imaging technique. The infrared reflectivity image on the sample surface revealed that the metallic (or superconducting) and insulating phases coexist in contrast to the monochromatic metallic character in the slow cooling condition and they have different magnetic field dependences.

O11-2

Atacama Large Millimeter/Submillimeter Array ALMA

T. Hasegawa

O11-3

Imaging Technique of Radio Interferometers

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Radio interferometers for astronomical observations are indirect imaging devices. It directly measures spatial coherence function (visibility) of astronomical objects (brightness distribution). If we obtaine complete samples of the coherence function, then, we can easily estimate astronomical images by direct Fourier inversion. However, we only measure the visibility for limited range of spatial frequency. Measured visibility often include some errors in amplitude or phase. Sometimes, imaging field of view is smaller than spaitial size of astronomical objects due to main beam width limitation of each element antenna. For these problems, many kinds of imaging techniques from design of instruments to data processing have been developed.

This paper reviews these techniques and shows how we apply those in design of Atacama Large Millimeter / Submillimeter Array (ALMA), which is being constructed in Northern Chile by National Astronomical Observatory Japan (NAOJ) with international collaboration.

O11-4

Multi-wavelength Imaging of Solar Plasma

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Solar atmosphere is filled with plasma and magnetic field. Activities in the atmosphere are due to instabilities of the manetized plasma. To understand the physical mechanisms of activities / instabilities, it is necessary to know the physical conditions of magnetized plasma, such as temperature, density, magnetic field, their spatial structures and temporal developments. Remote sensing technique is necessary to measure physical parameters of solar atmosphere from the Earth. Multi-wavelength imaging is essential for this purpose. Imaging observations of the Sun at microwave (Nobeyama Radioheliograph), X-ray (GOES/SXI telescope), EUV (SOHO/EIT telescope, TRACE satellite) and optical (SOHO/MDI telescope and many ground based optical telescopes) are routinely going on. Due to free exchange of original data among solar physics and related field communities, we can easily combine images covering wide range of spectrum. By the combination, we can get physical pictures of solar plasma and magnetic field at various location and temperature range.

The current standard model of solar activities is based on magnetic reconnections: release of stored energy in the form of magnetic field by reconnection causes various active phenomena on the Sun such as solar flares. However, recent X-ray, EUV and microwave observations with high spatial and temporal resolution show that dense plasma is involved in activities from the beginning. Based on these observations, I have been proposing high-beta scenario of solar activities. This mechanism is very similar to high-beta disruptions in magnetically confined fusion experiments such as TOKAMAKs. Magnetic field in the solar atmosphere is convex outwards and this configuration is unstable when the loop is filled with high pressure plasma or high velocity flow along the loop.

Movies of solar flares at various wavelengths will be presented and the necessity of high-beta interpretation to understand solar activities will be shown.

O11-5

Carbon redeposition on tungsten under high-flux,low-energy ion irradiation at elevated temperatures

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This work concentrates on the studies of the anomalous deep penetration of C in W observed under high-flux (10^{17}-10^{19} $cm^{-2}s^{-1}$) of 0.5 –1.0 keV ion bombardment at various temperatures, up to 1073 K. A carbon amount ranging from 0.5-10at% was deliberately introduced into an hydrogen ion beam as ions like CH_x^+ and $C_2H_4^+$ to study the formation of W and C mixed layers. Using weight loss experiments, the carbon amount was measured after successive fluence steps of about $2{\cdot}10^{17}$ cm^{-2} each. Surface atomic compositions were analyzed by X-ray photoelectronic spectroscopy. For profiling, the etching depth was measured with a surface profile-scanning technique. X-ray diffraction measurements were performed using characteristics X-rays from Cu (Cu KA).
The samples were fabricated in the following way: 2 µm-thick tungsten films were deposited on stainless steel (AISI 304) substrates 20x5x0.2 mm^3 in size using a magnetron sputter deposition technique. The XRD patterns of as-deposited W films demonstrated a nanocrystalline microstructure with the mean size of crystallites around 45 nm and characteristic peaks of c-W(200) at 35.5° and c-W(210) at 39.9&deg. The surface coverage of carbon atoms as a function of carbon ion concentration in ion beam was studied. The C profiles in W demonstrate that up to 700K the C penetration depth does not exceed 30 nm and does not depend on the surface coverage by C atoms. As the temperature exceeds 700K, the efficiency of carbon transport from the surface in to the bulk starts to depend on the surface coverage of W by C atoms. Two cases can be distinguished: (i) when the W surface is completely covered by C atoms, the experimental distribution C profiles in W are in agreement with modeling results considering the balance equations including deposition, surface erosion and diffusion; (ii) when W surface is partially covered by C adatoms, anomalous deep C penetration depths in W have been registered. There is evidence that dynamic state of surface creates a quite imperfect near-surface layer. This layer is both physically and chemically distinct from the bulk material. In this way differences in chemical potentials between ions irradiation surface, bulk and grain boundaries are established. The excess chemical potential of the surface relative to grain boundaries produces a net flow of adatoms into the grain boundaries and generates compressive stress. It explains the deep tails of C penetrating nanocrystaline in W at elevated temperatures. The continuous amorphous C film on W blocks the access of activated C adatoms to grain boundaries.

O11-6

Multi-functional Diagnostic Method with Tracer-encapsulated Pellet Injection

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In recent years magnetic plasma confinement experiments for fusion energy have been well developed. The physical mechanisms of the particle and heat transport, however, are not yet well understood, although the knowledge about the transport will seriously affect the design of a reactor. Conventional techniques such as impurity pellet injection or laser blow-off method are not well suited for the local measurement because the impurity source profile becomes rather broad. Considering such present status, we developed a Tracer-Encapsulated Solid PELlet (TESPEL) for local transport study on the Large Helical Device (LHD). It is one of the simplest ideas to study the confinement of impurities and other plasma properties. A TESPEL consists of polystyrene polymer as an outer shell, the diameter of which ranges from 0.3 to 0.9 mm, and tracer particles as an inner core. The special features of this method are: (a) local deposition inside the plasma, (b) the deposited amount of the tracer in the plasma can be known precisely, (c) relatively wide selection of tracer material is possible. From the experience of developing the TESPEL production technique and injection experiments, it is found out that the TESPEL technique has a multi-functional diagnostic capability. This is essentially due to the flexibility of pellet size and wide selection of tracer material. The features of this TESPEL injection technique are: (a) to study impurity transport properties such as diffusion coefficient D and inward pinch velocity V with the temporal evolution of line emissions from the tracer particles measured by a soft x-ray pulse height analyzer and a vacuum ultraviolet spectrometer, respectively, (b) to investigate the temperature increase of the core plasma in case of a relatively small pellet injection, which is probably caused by a steep temperature gradient production in the edge region, (c) to observe heat diffusivity from the cold pulse propagation due to TESPEL injection, (d) to observe the difference in the transport property at the locations inside the magnetic island and outside of that, (e) to observe energy distribution of high energy particles with using charge exchange process in the pellet cloud together with the information about the cloud density of TESPEL obtained from the Stark broadening of a Hydrogen line in the ablation cloud, (f) to observe local transport property with light emission due to the charge exchange recombination of tracer particles with a heating neutral beam, and (g) to observe detailed line emissions from the various atoms under the relevant plasma condition. Furthermore, a Tracer-Encapsulated Cryogenic PELlet (TECPEL) has been also developed. This has an advantage in absence of carbon in the outer layer of the pellet. The TECPEL injector was already installed at LHD in the end of 2005, and the preliminary pellet injection experiments were done.

Poster Session 1(plasma)
Categories 5, 7, 8, 13

P5-01

Electron Temperature Measurement And Study Of Istabilities And Sawtooth Behavior In IR-T1 Tokamak By E.C.E Diagnostic

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A suitable instrument for electron temperature measurement in tokamak is electron cyclotron emission(E.C.E) diagnostic.For measurement of this paremeter in IR-T1 tokamak heterodyne radiometer was used.this 5 channel system works in K_{α}-band and has a very fast response time and good resolution freguency for IR-T1 tokamak with R=45cm, a=12.5cm, B_t=0.6-0.8T, I_p=20-40KA.

This receiver was used outside the tokamak in horizontal and vertical direction to Bt,and with second harmonic Of X-mode,and electron temperature was measured.

Also, instability and sawtooth behaviore in diagrams were observed,when plasma current is reached to certain value,and their characteristics according to E.C.E channel region with respect to plasma center and plasma edge was studied.

And also effects of B_t,B_{Θ},RHF and gas pressure on electron temperature and sawtooth behavior have been studied.

Details of results will be discuss in the full paper.

P5-02

Effects of relativistic and absorption on ECE spectra in high temperature tokamak plasma

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The importance of a relativistic frequency downshift effect on electron cyclotron emission (ECE) in high temperature plasma is well recognized since the relativistic effects modify the relation between the frequency and the spatial position. Before evaluating the total ECE radiation, the study of ECE spectra characteristic in various sight line of observation is important. For the measurement of electron temperature profile ($T_e(r)$), the 2nd harmonic extraordinary mode of ECE in a tokamak is usually observed in perpendicular to the magnetic field (B_t) along the equatorial plane. When the angle between the observation sight line and the equatorial plane is increased or the angle between the sight line and the B_t is changed, the characteristics of the ECE spectra are changed by the effects of relativistic and absorption. The characteristics are also changed by the distribution function. The characteristic of ECE spectra on various sight line of observation in the tokamak has been studied in detail.

We consider the features in the ECE spectra that are different from the normal $T_e(r)$ measurement that the sight line is perpendicular to B_t from low field side in the equatorial plane in tokamak. When the angle between the observation sight line and the equatorial plane is increased, the overlapping region between 2nd and 3rd harmonics shrinks and the relativistic effect of only one harmonics will be revealed. We consider the dependence of ECE spectra on the electron density (n_e) in the case of the vertical sight line. The radiation is observed from only one resonance frequency region. For low n_e case, the ECE spectra are similar to the shape of emissivity. That is, the 3rd harmonic ECE increases with frequency slowly at the just higher 2nd harmonic non-relativistic EC frequency ($2f_{ce}^0$) and decreases with the frequency rapidly at the just lower 3rd harmonic non-relativistic frequency ($3f_{ce}^0$). When the n_e increases, the 3rd harmonic ECE on increases with frequency rapidly at the just higher $2f_{ce}^0$, and decreases with the frequency slowly at the just lower $3f_{ce}^0$. The high optical thickness due to the high ne results in these features. Next, in the case of the observation from the high field side in the equatorial plane, the relativistic effects reveals strongly compared with the observation from the low field side. The ECE shifts to the lower frequency by the relativistic effect. There is the overlapping region of frequency between $3f_{ce}^0$ at the outer side of periphery and $2f_{ce}^0$ at the inner side of periphery. The emission is absorbed at the overlapping region, and emission decrease. The combination between the relativistic and absorption effects results in the peak near the overlapping region.

We will present the feature of ECE spectra in the case of oblique propagation to B_t.

P5-03

Suprathermal electron distribution diagnostic for SST-1 tokamak

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The interaction of high power microwaves with plasma, create non-Maxwellian high-energy electrons known as suprathermal electrons, results in parallel velocity as well as perpendicular velocity diffusion which competes with the collisional relaxation mechanism of the plasma, so that evolution of space averaged electrons distribution is governed, which describes both parallel and perpendicular velocity redistribution. These suprathermal electrons and its distributions are effectively collisionless and are especially interesting for the study of anomalous transport in thermonuclear plasmas, since neoclassical transport relies on collisions. The theories for the anomalous transport are based on microturbulence, of either electrostatics or magnetic origin. Probing of the microstructure of the magnetic field is possible because these electrons are virtually collisionless from certain energies onward and therefore follow the field lines.
A suprathermal electron distribution diagnostic has been conceived and designed, using an ellipsoidal mirror, a plane mirror & broadband microwave corrugated waveguide, as wave collection and transport system, and a fast-scanning polarizing Michelson interferometer, which is capable of viewing the plasma vertically (constant magnetic field, Bf) along a chord having magnetic field 3.22 tesla and terminated by a highly absorptive SiC view dump. Both Extraordinary (X) mode and Ordinary (O) mode polarizations of Electron Cyclotron Emission (ECE) at optically thin harmonics will be collected under a variety of plasma conditions, during high power microwave injection (for example, lower hybrid current drive, LHCD) in the upcoming SST-1 Tokamak. A simplified theoretical model has been developed for the signal estimation by considering single particle emissivity and drifted Maxwellian distribution function during LHCD. The intensity distribution as a function of frequency of ECE at several harmonics for different parameters of suprathermal electrons having: temperature 50 - 500 KeV, density 0.1 to 10% of bulk electrons, magnetic field 1.5 to 3.5 tesla and different phase velocities of LHCD system have been computed. Analysis consisted of putting a variety of distribution functions into developed ECE code. The quasi-optical systems, using mirrors and corrugated waveguide as a wave collection and transport it through the interferometer (which will scan 100-1000 GHz spectrums) to the detector, have been designed using the concept of Gaussian beam optics in order to produce a system that is efficient over the entire spectral range.

P5-04

Protection Filters in ECEI Systems for Plasma Diagnostics

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For plasma diagnostic imaging systems such as the electron cyclotron emission imaging (ECEI) system, spurious rf heating power may saturate or even damage the mixer arrays. Without protection, the sensitivity of the mixers can significantly decrease or in the extreme case, the diodes can even be burnt. A metallic dichroic plate is usually used to rejection the spurious rf heating power. However, as a low pass filter, the dichroic plate can not be used when the frequency of the heating power is in the middle of the frequency range of interest. Consequently, a frequency selective surface (FSS) has been introduced as a planar filter in ECEI systems. FSSs can work as low pass, high pass, and band stop filters according to the various system requirements. Also, as a thin, light, planar filter, it is very easy to mount in imaging systems. This paper will focus on the design and fabrication of the FSS notch filter applied in TEXTOR, which is used to protect the imaging array from stray 140 GHz ECRH power. The filter is used in TEXTOR due to its deep rejection, and excellent angle insensitivity. The design procedure will be presented. The new fabrication technique Electro Fine Forming technology (EF2) will also be introduced. FSS filters in the millimeter wave range also have possible applications in imaging systems in other fusion machines such as KSTAR, DIIID, and LHD.

P5-05

Imaging meso-scale structures in TEXTOR

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The detection and control of instabilities in a tokamak is and will continue to be one of the exciting challenges in fusion research on the way to a reactor, as will be the understanding of these mechanisms. Thanks to a combination of an innovative 2D temperature imaging technique, the ECE-Imaging (ECEI) system, a versatile ECRH/ECCD system and a unique possibility to externally induce tearing modes in the plasma, TEXTOR is able to make pioneering contributions in this field. Whereas previously the strength of the ECEI system in unraveling the sawtooth physics has been demonstrated, this paper focuses on three other meso-scale phenomena in tokamaks: m=2 tearing modes, ELM events and structures in the stochastic boundary. In all cases the 2D-ECEI diagnostic can resolve features not attainable before, allowing a direct comparison with theory.

Tearing modes can be induced externally at TEXTOR by the Dynamic Ergodic Divertor (DED). Operation of the DED at sufficiently high current will excite an m/n=2/1 tearing mode. The suppression of these with the ECRH/ECCD system has contributed to a deeper insight in the relevant processes. With the ECEI data the m=2 island evolution can be visualized. From this it is concluded that heating rather than current drive is responsible for the stabilization in these experiments.

If the DED system is operated at another mode configuration, only the plasma edge is affected by the perturbation fields. In that case temperature structures appear on ECEI at the very edge, mainly determined by the connection length in the laminar zone. The lower edge temperature during DED confirm the enhanced transport levels due to the perturbation field.

One possible application of the stochastisation of the edge by the DED could be the mitigation of ELM’s. Recently experiments are performed to access the H-mode in TEXTOR, revealing ELM-like events. Although temperature information of these instabilities are partly obscured by density related effects, ECEI can provide valuable information on the ELM’s.

P5-06

Development of ECE Imaging System on LHD

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It is considered to be one of the major issues to clarify the behavior of various instabilities and relations between instabilities and plasma confinement. ECE imaging (ECEI) is a promising method to measure electron-temperature profile and its fluctuations precisely. An ECEI system is composed of a detector array, quasi-optical system, and IF system. Each subsystem plays following roles. The optical system is composed of optical mirrors and dielectric lens. These optics are utilized to focus ECE from plasma on the detector array within the specific bandwidth. In the present plan of the beginning experiment, we will collect the fundamental component of ECE with frequency range from 70 to 76 GHz. The ECE is then received by the detector array, and is frequency-converted to IF signal by means of LO wave. In the IF system, signal is then fed to power dividers and bandpass filters to resolve radial temperature distribution, since the frequency of ECE is proportional to magnetic field strength. While poloidal and toroidal temperature distribution is obtained by 2D arrangement of the ECE detector, since the signal obtained by each detector element is corresponding to individual poloidal and troidal measurement point. The filtered IF signals are then detected by squared detection, and digitized by A/D converters. By utilizing the detector array and the IF system, measurement of 3D temperature distribution can be achieved.
Our research has dedicated to develop high-performance ECE detector array and the IF system on a dielectric substrate by means of microwave integrated circuit (MIC) technology for measurement of precise electron temperature distribution. In the recent experimental cycle of LHD, we have confirmed that the signals which are proportional to electron temperature have been obtained by using prototype 3 by 1 detector array and the IF system.
In the conference, we will present details of these measurement and the system and more multi-channel plan which will be utilized in the next experimental cycle on LHD.

P5-07

Improvements of CO2 laser heterodyne imaging interferometer for density profile measurements on LHD

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After installation of CO_2 laser (wavelength 10.6 μm) heterodyne imaging interferometer (CO_2 HI) in 2001, continuous developments were done to improve capability and stability of the operation. The CO_2 HI works without phase jumping at high density ($>1\times10^{20}m^{-3}$), where the existing far infrared laser (wavelength 118.9μm) interferometer suffers from phase jumping due to the reduction of signal intensity caused by refraction. However the second interferometer is required to compensate mechanical vibration. A Yag laser (wavelength 1.06 μm) heterodyne imaging interferometer are presently used for the vibration compensation. Frequency drifts of YAG laser made vibration compensation unreliable and sometimes caused phase run away effects. In order to solve this problem, the path length of probe beam and local beam was equalized, and then phase drifting was eliminated under frequency shifting. The feedback control of pellet injection became possible by this improvement. Three imaging optics will be installed in 10th experimental campaign in 2006~2007. The whole region of the plasma cross section are covered with three slab beams. Two 32 ch and one 16ch HgCdTe photoconductive detector (total 80ch) will be used and chord separation 7.5mm~15mm. Image of integrated line density are measured from imaging optics. Imaging optics consists of combination of parabolic mirrors and spherical lenses. The spherical aberration was minimized by the adjusting the distance of these optics. It was found cross talk of signal deforms measured image. This was reduced by the use of lower heterodyne beating frequency and completely eliminated by the modification of elements structure.

P5-08

Two dimensional phase contrast imaging of micro-turbulence in LHD

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Phase contrast imaging, a well-established technique to image phase differences within an object, is employed on LHD to measure the spatial structure of plasma density fluctuations. The novel aspect of the diagnostic is the use of 2D imaging, which delivers spatial resolution along the line of sight, providing tremendous advantage in physical interpretation. Similar systems on other fusion devices have used only 1D imaging can therefore only provide longitudinal spatial resolution either time-multiplexed or in different shots. Concomitantly, a novel analysis method has been developed. The images are processed using correlation techniques and maximum entropy power spectrum estimation, to aid in improving the spatial resolution and reducing artifacts.
A CO_2 laser (λ=10.6μm) is injected as a probing beam vertically in a near-poloidal cross-sectional plane, passing close the the magnetic axis. A two dimensional image of the beam (size 87x30mm) is captured using a 6x8 detector array, in the toroidal and major radial directions respectively. The propagation direction of fluctuations within this image is used to provide localization along the line of sight, on the well-established basis that fluctuations are filamentary structures along field lines, and the fact that the variation of the magnetic pitch angle, within the image, is large across the line of sight (~80°). The attained radial resolution better than ~0.05 of the minor radius, and the measurable fluctuation wave numbers (k) are in the region $0.1<k<3mm^{-1}$. A flexible optical system has been designed to adjust the measurable range of k.
Radial profiles of the fluctuation phase velocity are computed, which may help to classify the physical nature of the instabilities (e.g. TEM or ITG). The fluctuating component of the (spatially averaged) phase velocity can also be extracted, valuable for assessing electromagnetic component of the fluctuations, as well as provide an upper bound on the anomalous particle flux.

P5-09

Instrumental capabilities and limitations of two-dimensional phase contrast imaging on LHD

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A novel phase contrast imaging is employed for diagnostics of plasma density fluctuations on LHD. With the use of two dimensional 48ch (6x8) detector array and CO_2 laser probe beam this technique permits observation of radial profiles of density fluctuation during single discharge either within entire plasma diameter in overview mode or within some fraction of the diameter in zoom mode. Simultaneously velocities of fluctuation in laboratory frame can be determined as well as velocity fluctuations. Analysis of system performance was made with the use of numerical calculations and experimental tests. The targets for the analysis include wave number and spatial resolution of the method, contrast of instrumental function, which determined low k signal leakage into high k spectral region, focal depth of optical system for different wave numbers of fluctuations and others. Possible instrumental contribution into effects observed in plasma experiment as up/down asymmetry in intensity of density fluctuations and strong poloidal velocity shear are discussed. The role of shortcomings of optical system like distortion of optical front by diffraction on system apertures and by aberration on optical elements as well as not perfect collimating of probe beam are studied with numerical simulation and experimental tests. Suggestions for future upgrading of the diagnostics based on the obtained data of the system performance are advanced.

P5-10

Electron Density Measurement by Using a Multi-Channel Interferometer System in the Tandem Mirror GAMMA 10

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The tandem mirror GAMMA 10 utilizes an electron cyclotron resonance heating (ECRH) for forming a confinement potential. Fluctuation in the plasma is important to be measured for studying the improvement of the plasma confinement by the formation of the plasma confinement potential. Density fluctuation is observed using microwaves, such as interferometer, reflectometry and Fraunhofer diffraction method, and electrostatic probes. We have constructed a new multi-channel microwave interferometer system for measuring the line integrated plasma density profile and density fluctuation profile in a single plasma shot. It is designed using Gaussian-beam propagation theory and ray tracing code. The system is configured as a heterodyne interferometer consisting of a 70 GHz (1 W) IMPATT oscillator and a 150 MHz oscillator. The main plasma confined in GAMMA 10 is produced and heated by ion cyclotron range of frequency power deposition. The potentials are produced by means of ECRH at the plug/barrier region. Moreover, the electron heating is achieved by the central-ECRH at central region. They cause the density and temperature increase in the central cell. The typical electron density, electron and ion temperatures are about 2×10^{12} cm^{-3}, 100 eV and 5 keV, respectively. Fluctuation with coherent mode in several kHz is excited in the hot-ion mode plasma. When the ECRH is applied, the intensity of the density fluctuation of coherent mode is suppressed. In that time, radial potential distribution, i.e., electric fields change along with the formation of plug potential. From this behaviour it is deduced that the fluctuation deeply relates to the potential formation and improvement of the confinement. Moreover, we made pellet injection experiments for density increase. We successfully obtained the radial density profiles in the pellet injection experiments for the first time.

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P5-11

Reflectometry for Density Fluctuation and Profile Measurements in TST-2

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Microwave reflectometry is a useful diagnostic and is applied in many fusion plasma devices. It is able to measure the electron density fluctuation and the density profile. The Tokyo Spherical Tokamak-2 (TST-2) at the University of Tokyo is a spherical tokamak (ST) device with a central density of about $2 \times 10^{19} m^{-3}$ [1]. At TST-2, a radio frequency (RF) heating experiment using high harmonic fast wave (HHFW) is in progress now [2]. The frequency of HHFW is 21MHz and the power is up to 400kW. To measure the density oscillation induced by this RF heating, a reflectometer with the frequency range from 26.5GHz to 40.0GHz was designed, constructed and applied to TST-2. RF heating using HHFW is an efficient method for STs [3]. Electron cyclotron waves and lower hybrid waves, which are often used to heat conventional tokamaks cannot propagate to the core of plasmas which have large dielectric constants. HHFW has a good accessibility to these large dielectric plasmas and is believed to be efficiently absorbed by electrons. The reflectometer is designed to measure this density oscillation and the density profile. The performance of the reflectometer was simulated by Kirchhoff integration method before construction. Kirchhoff integration is useful to calculate the propagation of the microwave in three-dimensional arrangement assuming the electric field is a scalar field. The arrangement of the mirrors and the horn antennas were optimized by the calculation, and the performance of the reflectometer was evaluated. Microwave launched from the horn antenna is reflected with two concave aluminum mirrors to make a spot at the cutoff surface inside the plasma. The reflected wave from the cutoff surface includes information on fluctuations and is received by another horn antenna next to the launching antenna. The received signal is quadrature demodulated by reference wave and sampled by 25MHz ADCs. The fast oscillating signal around 21MHz is used for density fluctuation measurement induced by RF and the slow oscillating signal is used for density profile measurement.

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P5-12

Microwave Imaging Reflectometry in LHD

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The microwave reflectometry is a radar technique for the measurement of the electron density profiles and fluctuations by probing the density-dependent cutoff layer in the plasma . A multi-channel reflectometry system equipped with an imaging optics has been developed for the microwave imaging reflectometry (MIR). It has a potential to obtain the 2-D/3-D image of the MHD turbulences and instabilities with good time and spatial resolutions. The MIR system is under development in the Large Helical Device (LHD), which is a superconducting heliotron-type fusion device. The right-hand cutoff layer is utilized as a reflection surface. The angle of an ellipsoidal mirror installed inside the vacuum chamber is remotely adjustable with the ultrasonic motor in order to optimize the illumination angle for the wider range of the plasma parameters. The beam paths near the reflection surface are calculated with the ray tracing code, and the beam patterns are numerically calculated by using the FDTD method. Experimental examples in the LHD 10th campaign are presented at the conference.

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P5-13

Multi-channel Microwave Reflectometer with Fermi Antenna Receivers

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Reflectometry is now widely used in both Tokamak and other magnetically confined plasmas[1]. It has an advantage of detecting local plasma density behavior with a high spatial resolution. Microwave imaging reflectometry[2] is recently develop as an advanced diagnostic system and provides excellent advantages compared with conventional systems. To compose this system, it is necessary both to design an optical system and to develop an imaging antenna array. Several imaging antennas, such as a bow-tie antenna, a Yagi-Uda antenna, a dual-dipole antenna etc, have been developed. The tapered slot antenna(TSA) that we are developing is one of the candidates. A TSA has been firstly developed in electrical communication researches. It has a nearly symmetrical radiation pattern compared with that of a bow-tie antenna and its bandwidth is relatively broad. It can be adopted as an array antenna owing to its planer shape and fabricated with a low cost due to its compactness and a light-weighted structure. Recently, a new TSA called "Fermi antenna" in the frequency range of 35GHz and 60GHz has been developed in Tohoku University[3]. This has a tapered structure defined by the Fermi-Dirac function and a corrugated structure along the outer edge of the antenna to reduce side-lobe intensity. It is found experimentally that the radiation-beam widths in the E- and H-plane are almost equal to each other and the side-lobe levels are low in the Fermi antenna.

We designed a Fermi antenna with a corrugated structure for X-band according to a scaling law shown in Ref. 3. We attained a 3dB-beamwidth of 32 degrees in the E-plane and 37 degrees in the H-plane at 12GHz. Directivity of a Fermi antenna with corrugated structure is 2dB better than that of a linear TSA. By optimizing the strip line structure according to the equivalent circuit model, a VSWR less than 2 is obtained in the bandwidth of 8-18GHz. Plasma behaviors in the HITOP device[4] are measured with a reflectometer with two Fermi antenna receivers. Time evolution of the cutoff layer and plasma rotation velocity measured by the reflectometer are in good agreement with an electrostatic probe measurement.

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P5-14

Design of the 48, 57 μm Poloidal Polarimeter for ITER

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Control of the current density profile becomes a paramount issue for the modern tokamak experiments. Polarimetry, a powerful diagnostic tool, can provide information on the density and magnetic field, utilizing the Faraday and the Cotton–Mouton effects in a magnetized plasma. The polarimeter under study is based on the system that was originally proposed for ITER-98 and the present ITER[1] designs. The modified system featured two fans of quasi-perpendicular chords viewing the plasma through equatorial and upper ports. The updated system[2] will be operating at a wavelength of 48, 57 μm (instead of originally proposed 118 μm). The main advantage of the smaller wavelength is the significantly smaller beam refraction along laser beam lines. It will allow increasing the maximum number of chords via the equatorial port for viewing the plasma by penetration through the blanket modules, as well. The beams are reflected back along the same path through the plasma by means of circular shaped retroreflectors. For the best optimization of the plasma coverage up to six chords in vertical direction via an upper plug are proposed. The upper chords can give a possibility to monitor the Shafranov shift, independently. This article will present the present status of the on-going design and will address issues as sensitivity and accuracy, refraction, Gaussian beam ray-tracing, beams and mirrors alignment as well as some other specific details.

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P5-15

Weakly Relativistic K-band Oversized Backward Wave Oscillator with Bragg Reflector at Input End of Slow Wave Structure

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Microwaves at moderate-power level or high-power level are demanded for widespread applications including plasma heating, plasma diagnostics, telecommunication systems and radar systems. Slow-wave devices such as backward wave oscillator (BWO) and traveling wave tube can be driven by an axially injected electron beam without initial perpendicular velocity and has been studied extensively as a candidate for a high-power microwave source. We study oversized BWOs driven by weakly relativistic electron beams less than 100 kV. In order to increase the frequency and/or the power handling capability, oversized slow-wave structures (SWSs) have been successfully used, in which diameter of SWS is larger than free-space wavelength of output electromagnetic wave by several times or more [1, 2]. Recently, the performance of oversized BWO is improved by improving the SWS and the beam shape. The output power increases up to about 500 kW in K-band (around 25 GHz) and about 200 kW in Q-band (around 41 GHz) [2]. The input end of SWS (beam entrance) is usually terminated to a mesh anode or a cutoff waveguide in order to reflect the microwave radiation. In oversized BWOs, electromagnetic modes responsible for the radiation are a surface wave. The field decreases sharply from the SWS wall. For an efficient beam interaction with the surface wave, the beam should propagate near the wall. Hence, the beam radius became too small to interact with the surface waves if a cutoff waveguide was used. In the oversized BWOs, a mesh or a RF reflector at the anode was used in order to separate the SWS region from the electron beam diode [1, 2]. For practical high-power devices, it is desirable to remove such obstacles which may intersect the high current electron beam. In this work, a Bragg reflector is tested in the K-band BWO experiments as a reflector of microwave at the input end of SWS. The effects of Bragg reflector on the high-power performance of the weakly relativistic oversized BWO are examined experimentally.

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P5-16

Advanced Fabrication Method of Planar Components for Plasma Diagnostics

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As the importance of microwave imaging diagnostics and satellite communications are increasing, the fabrication of high performance millimeter-wave planar antennas and high-frequency filters are essential. One of the methods is to use fluorine resin as an antenna substrate. If the planar antennas are used as transmitting or receiving antennas, we can control the beam direction of the antennas and decrease the height of the antenna against that of horn antenna.
However, there are two problems to be solved, low degree of adhesion between copper foil and fluorine substrate and the edge shape of antenna pattern. We have proposed several methods to solve those problems. One solution is a surface treatment of fluorine substrate to increase the peel strength of copper foil. The other is a fabrication method using electro fine forming (EF2) technology that gives excellent pattern without side edges.
We report on the results of surface treatment of fluorine films by using graft polymerization and the measurement of dielectric constant before and after the treatment. The antennas fabrication using EF2 technology is also introduced. And the measurement results of characteristic evaluation of millimeter-wave antennas will also be presented.

P5-17

Development of a Tera Hertz Gyrotron as a Radiation Source

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Gyrotron development is being advanced in two ways. The major way is development of high power, millimeter wave gyrotrons for heating and current drive for fusion plasma. It is going world-widely and has achieved around 1MW output power for long pulse operation (longer than several tens second or quasi CW) at the frequency of 170 GHz or 140 GHz. On the other hand, medium power, high frequency gyrotrons are being developed in several institutions in the world. In the cases, high magnetic field and higher harmonic operations are used for increasing operation frequency. Such gyrotrons have already covered wide frequency range in millimeter to submillimeter wavelength region and been applied as submillimeter wave radiation sources for wide fields including plasma diagnostics, electron spin resonance (ESR) specroscopy, new medical technology, and so on. These gyrotrons are only one high power stable THz radiation source and will be important and useful in future for development of high power THz technologies.
Our gyrotrons developed in FIR FU named Gyrotron FU Series belongs to the second type gyrotrons, that is, medium power high frequency gyrotrons. The series has achieved following items1), 1) frequency step-tuneability in wide range in millimeter to submillimeter wavelength region (from 38 to 889 GHz), 2) highest frequency (889 GHz) corresponding to the wavelength of 377μm by using second harmonic operation at the field intensity of around 17 T, 3) modulation of amplitude and frequency of the output, 4) stabilization of amplitude and frequency, 5) higher harmonic operations up to fifth and 6) high-purity mode operations at many cavity modes by installation of a carefully designed cavity. Also, we have achieved mode conversion from circular waveguide modes to a Gaussian mode for applications of our gyrotrons to many fields.
However, up to the present, gyrotrons have not achieved the operation at the frequency of one terahertz. This paper presents that a THz gyrotron with a pulse magnet has been designed, constructed and operated in FIR FU. It is developed as one of high frequency gyrotrons included in Gyrotron FU Series. The gyrotron has already achieved the first experimental result for high frequency operations whose radiation frequency exceeds 1 THz. In this presentation, the design detail and the operation test results for sub-terahertz to terahertz range are described. The second harmonic operation is confirmed experimentally at the expected frequency of 1.005 THz due to TE6,11 cavity mode at the magnetic field intensity of 19.0 T.

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P5-18

Utilization of Terahertz Imaging Technology to High-Temperature Plasma Diagnostics

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Recently development of the terahertz imaging technology is making rapid progress. Especially the technique utilized of the terahertz pulse such as terahertz time domain spectroscopy has been applied to the material physics and making a new research field. On the other hand, in the field of the fusion plasma experiment the high temperature and high number dense plasma has been achieved to generate in the experimental device and there is need to develop a new diagnostic tool. The frequency range connecting from the millimeter to the infrared, that is terahertz, is expected to develop for the plasma diagnostics. Here we will report the recent terahertz technology and the possibility and problem of the application to the plasma diagnostics.

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P5-19

Laser Absorption Spectroscopy for Diagnostics of a Neutral Helium Beam

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Diagnostic neutral beam is required to be well controlled on population in metastable state in terms of accurate evaluation of the beam-attenuation length. In this paper, measurement method of population density of metastable state in neutral beams is described, where metastable helium atom is measured using laser absorption spectroscopy.
Laser absorption spectroscopy is a popular method to measure atomic density in laboratory plasmas. On the other hand, applying the method to beam diagnostic is sometimes ambitious since beam density is much lower than that of the plasma. In laser absorption spectroscopy, density resolution, which corresponds to the lowest measurable density, is mainly determined by dynamic range of the detector. The density resolution is estimated to be 10^6 cm^{-3} for metastable helium atom if an infrared photomultiplier tube is used without any synchronizing technique. Using a lock-in detection technique is proposed to detect metastable state in the neutral helium beam produced in a tabletop ion source.
Experiments are performed in a hollow cathode device for production of metastable atoms (PROMESTA device). Inner diameter of the cathode is 10 mm and its length is 40 mm. Two anodes, which have the same inner diameter with the cathode, are positioned at both ends of the cathode with 2 mm gaps. Helium gas flowing from one end through the hollow cathode is excited to a metastable state, $2\ ^3S$, by electron collision in the hollow cathode plasma. An external cavity diode laser (λ = 1083 nm) is used to measure the $2\ ^3S$ metastable state exciting to $3\ ^3P$ state. The laser beam, which is directed along the hollow cathode axis, passes through the excitation region and downstream free-diffusion region, then it is detected by a photo diode. From the absorption spectrum line density of the metastable atom is obtained.

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P5-20

Design of bolometer diagnostics for the KSTAR

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A 12 channel resistive bolometer[1] array and an infrared imaging video bolometer (IRVB)[2] have been designed for the Korean Superconducting Tokamak Advanced Research (KSTAR). In the 2nd campaign (2009), the 12 channel resistive bolometer array will be installed at the mid-plane tangential port, with the array viewing horizontally, and an Abel inversion will be carried out for a major radial profile of the radiation emissivity of the circular cross-section plasma. In the 3rd campaign (2010), an IRVB will be installed at the port of the resistive bolometers and the results of the resistive bolometer and the IRVB will be compared. In the 4th campaign (2011), the 12 channel resistive bolometer array will be moved to the divertor. The calibration constants of the 12 channel resistive bolometer such as the sensitivity, K, and the cooling time, τ_c , have been obtained by the *In situ* calibration[4].

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P7-01

Helium measurements using the pellet charge exchange in Large Helical Device

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In Large Helical Device (LHD), it is possible to perform the simulation experiment of the α particle heating by using the ion cyclotron resonance heating (ICH) because high-energy particle generated by ICH is well confined in the plasma. The neutral particles (mainly hydrogen), which are generated by the charge exchange between the high-energy ion and the background neutrals, can be observed by using them. However a few neutral helium particles can be observed because α particle (or fully ionized helium) can emit only by double charge exchange process. Therefore we also introduce the pellet charge exchange system (PCX). The diagnostic pellet is injected to the plasma in order to obtain the charge exchange neutral particle, which is produced by the charge exchange reaction between the ablated pellet cloud and α particle or high-energetic particle. The helium distribution measurement in helium plasma is demonstrated.

P7-02

New 20-channel Diagnostic for Angle-Resolved Fast Particles Measurements in LHD.

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A new multi-channel diagnostic for fast particles has been developed and successfully tested on the Large Helical Device (LHD) during 2005-2006 experimental campaign. The number of simultaneously used channels was significantly improved from 2 to 20 channels and additional improvements for noise reduction have been made. Same time location of the diagnostic has been changed that allowed one to make measurements in a much wider range of pitch angles from perpendicular to tangential (90-160 degrees). All these improvements allow one to make time, energy, and angle-resolved measurements of charge exchange neutral particles in a single plasma discharge and to check the presence of fast particles loss-cones from LHD plasma in different heating regimes. This new diagnostic can be a very helpful and powerful tool in studying of fast particle distribution in such a complex helical plasma geometry like the one of LHD. Example data from plasma discharges are presented.

P7-03

A Method for Reconstruction of the Neutral Particle Source Function in Helical Magnetically Confined Plasma

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Multidirectional nonperturbing diagnostics based on high resolution atomic energy spectrometers are used on the Large Helical Device (LHD) to study the ion component heating mechanisms and fast ion confinement by measuring the escaping neutral particle fluxes. The particle source $g(E, \rho)$ is not localized in contrast to the methods employing a diagnostic neutral beam or charge exchange on a pellet cloud. Several possible approaches to the localization of such measurements on LHD were overviewed in [1]. A new 20-channel analyzer for simultaneous measurements of the energy resolved neutral particle flux along twenty observation lines at the angles ζ_i was described in [2].
This paper presents a numerical method realized in FORTRAN for the calculation of the neutral particle source function radial distribution $g(E, \rho)$ from line-integrated passive measurement data $\Gamma(E, \zeta_i)$. The basic integral relation between these quantities was given in [3] for LHD geometry along with the numerical simulation of the measured fluxes. The source function reconstruction algorithm requires the integral kernel calculation using the known geometry of measurements and the magnetic equilibrium data, a certain treatment of the singularity at $\rho = \rho_{min}$, and a regularization of the first kind Volterra integral equation.
The algorithm is suitable not only in particle diagnostic data analysis, but for any kind of radiation source function reconstruction as well, assuming the source to be equal on a magnetic surface. The reconstructed radial dependence provides additional information for comparisons and cross-checks using the local diagnostic data.

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P7-04

Analysis of energy spectra of fast ion in the Large Helical Device

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In toroidal helical devices, due to the absence of symmetry of magnetic field structure, fast ion orbits are much more complicated than those in tokamak devices. It is important to understand their behavior for future fusion reactor. As the simulation, the energy spectra of fast ions produced by tangentially injected neutral beams (NBs) have been measured by using a neutral particle analyzer (NPA) based on natural diamond detectors (NDDs) in the Large Helical Device (LHD).

As an evaluation formula of the energy spectra of fast ion produced by NB, on the basis of kinetic equation the analytical formula is derived. Kinetic equation is consisted of four terms, Fokker-Planck drag term describing the velocity relaxation, particle production term originating from neutral beam injection heating, particle loss term due to the charge exchange reaction with neutral particles, and particle loss term due to the loss cone in the velocity space. In the last term, whether fast ions are gone outside of the confinement field or not is determined by using the adiabatic invariants method. The distribution function is derived by integrating the kinetic equation as possible as analytical methods are used to reduce a computational time. The validity of the derived solution is appraised by comparing the energy spectra of fast ion numerically calculated based on the solution with those experimentally measured by NDD in LHD.

P7-05

Fast ion diagnostics for CHS experiment

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The Compact Helical System (CHS) project since June 1988 comes to a close at the end of August 2006. The CHS is a medium size helical device characterized by a low aspect ratio (R/a=1 m/~0.2 m). This project has primarily aimed at clarifying confinement properties of low aspect ratio helical plasma. Study on fast ion confinement has been one of key physics targets in CHS because of the symmetry breaking of the system and enhanced toroidicity. For this reason, various types of fast ion diagnostics have been developed and applied to the CHS device. In the early days' experiment of CHS which was in operation at the Higashiyama site of Nagoya University, our interest was mainly focused on issues related to ion orbit and/or loss cone structure. This was investigated through measurements of energy spectra of fast ions generated by NBI and ICRH by use of charge exchange neutral particle analyzer (NPA). Because NPA on CHS is capable of changing its viewing angle, it allows us to study confinement of fast ions over a wide range in their pitch angles. Neutron diagnostics consisting of proportional counters and plastic scintillator were also employed for similar purpose. We generated intentionally d-d neutrons due to beam-target reactions by injecting 1 % deuterium-doped hydrogen NB into deuterium target plasmas at the Higashiyama site. This is because decay of neutron emission rate after NB turn-off contains information of beam ion confinement. These diagnostics clearly showed that confinement of perpendicularly injected fast ions is poor as expected while tangentially co-injected transit fast ions are well confined. In the latter half of CHS project at the Toki site, we stressed on the studies on fast-ion-driven MHD instabilities and their effects on fast ion transport although the studies had already been started in the former half of CHS project. For this experiment, we have developed scintillator-based lost fast ion probe (SLIP), Faraday cup type lost fast ion probe (FLIP) and directional Langmuir probe (DLP) to detect flux of lost fast ions near the outermost magnetic flux surface, in addition to NPA. These have played an important role in study of anomalous transport due to fast-ion-driven MHD instabilities. In this paper, we review these fast ion diagnostics for CHS experiment. Also, experimentally obtained knowledge on the issues related to fast ions in CHS will be summarized.

P7-06

Effects of Radially Sheared Electric Field Analyzed with End-Loss Ion-Energy Spectrometers

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Remarkable effects of radially produced shear of electric fields E_r on the suppression of turbulent fluctuations with plasma confinement improvement are found in the tandem mirror GAMMA 10 by the use of signals of end-loss currents flowing from the central cell as well as the central-cell soft x-ray brightness [1-3]. Here, electron-cyclotron heating (ECH) for the formation of ion-confining potentials, φ_C, simultaneously leads to a significant rise in the absolute value of the central-cell potential and the associated formation of a strong E_r shear. The effects are observed in the form of remarkably different fluctuation levels and Fourier spectrum shapes. In association with the reduction of the fluctuations due to strong E_r shear formation, increases in ion and electron temperatures are found.

Recently, higher-power ECH in the central cell (200 kW) and plug (430 kW) regions produces stable central-cell plasmas (T_e=600 eV, $T_{i\perp}$=6.6 keV, and $T_{i//}$ for φ_C *trapped ions* of 2.0 keV with φ_C=2.3 kV) with azimuthal $E_r \times B$ sheared flow. As a result, the stored energy of φ_C trapped ions *exceeds* that of central-cell mirror trapped ions (represented by diamagnetism). This first result in tandem mirrors is based on the importance of $E_r \times B$ sheared flow effects on improvement in stabilization and confinement of plasmas.

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P7-07

Use of γ-ray-generating $^{6}Li+D$ reaction for verification of Boltzmann-Fokker-Planck simulation and knock-on tail diagnostics in neutral-beam-injected plasmas

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It is well known that the nuclear elastic scattering (NES) contributes to a certain extent to the slowing-down of suprathermal ions in fusion plasmas. In conceptual designs of next-generation fusion devices, 3.52-MeV α-particles are continuously produced and use of beam injection with energy more than 1 MeV is also considered. In such a case, the NES effects on slowing down of energetic ions may not be negligible compared with those due to Coulomb collisions. To know the NES effect on reaction rate coefficient and diagnose the plasma parameters in knock-on-tail-created plasmas, the analysis model which can consistently treat the distortion of bulk component of fuel-ion velocity distribution functions is required. We have evaluated the NES effect on burning plasma properties in ITER-like plasmas[1-3] on the basis of the Boltzmann-Fokker-Planck (BFP) model. For forthcoming burning experiments, verification of the BFP model by comparing with measured data in currently existing fusion devices would be meaningful. In this paper, the BFP calculations are performed assuming 50~200keV proton beam injection into the ^{6}Li containing deuterium plasmas ($n_e \sim 10^{19} m^{-3}$ and T=1~10keV) and knock-on tail formation in deuteron distribution function due to NES by injected proton is examined. Using the obtained deuteron distribution function, the 0.5MeV γ-ray emission rate by $^{6}Li(d,p)^{7}Li^{*}$, $^{7}Li^{*} \rightarrow ^{7}Li+\gamma$[4,5] is evaluated for various plasma states. The experiment to verify the BFP numerical model is proposed.

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P7-08

Observation of Molecular and Atomic Ions in recombination Plasma

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The knowledge of atomic and molecular processes in hydrogen plasma has become increasingly important for plasma processing, space plasma, and fusion reactors. In a recombination plasma at low temperature, vibrationally excited molecules, such as $H_2(v)$ or $D_2(v)$, persist in dissociation and ionization processes of the plasma volume. Thus, the plasma volume recombination associated with molecules in the recombination plasma is effective in enhancing the reduction of ion particle flux. However, the role of molecular ions in the plasma is still under discussion and various conclusions have been derived from the analysis of different experiments. In this study, we have carried out the experimental observation of molecular ions in H_2, D_2, and He mixture plasma in a linear plasma device, TPD-SheetIV. Measurements of the densities of molecular and atomic ions were carried out in hydrogen plasma with a hydrogen/deuterium gas puff. An “omegatron” mass analyzer, situated behind a small hole (Φ 0.5 mm) in the endplate with a differential pumping system, is used for analyzing ion species, while the electron density and temperature were measured using a Langmuir probe and a double probe.

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P7-09

Observation of Divertor Plasma Shift during a Discharge in Heliotron J

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A combination of a small target and a fast video camera is a very powerful tool to visualize the edge plasma behavior and/or the plasma-wall interactions with high spatial and time resolutions, which has been introduced for the edge plasma fluctuation study in Heliotron J [1]. Recently, the similar method is applied to monitor the diverted plasma flux position. In a low shear device like Heliotron J [2], the rotational transform has great importance in the core plasma confinement. In addition, it is closely related with the edge field topology, which is to be used for a "build-in" divertor in helical systems. To use the intrinsic edge field topology for a divertor, it is important to experimentally study the dynamic change of the divertor plasma distribution caused by the plasma discharge and its controllability.
To monitor the diverted plasma flux position, a rail-limiter type carbon target (a radial length of 16cm) was inserted to the periphery of Heliotron J plasma form the bottom of the torus and a video camera (250-500fps) was set at the opposite port. Two-dimensional images of visible light emission near the target were taken during discharges. A spontaneous radial shift of the brightest spot position on the target was clearly observed during a discharge indicating the shift of the diverted plasma flux position. The diverted plasma flux coming to the wall was also monitored with poloidal Langmuir-probe arrays [3]. It was also observed that the distribution of the diverted plasma density was shifted during a discharge. These findings are qualitatively consistent with each other. In some NBI or ECH discharges, bright spots were observed at unexpected position of the target from the field calculation. This suggests the possibility of this method as a detecting system for non-thermal particle flux.

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P7-11

Measurement of gas composition ratio of H-He mixture plasmas in Divertor Simulator MAP-II

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In a divertor region of the fusion reactor, many neutrals are mixed: desorbed or puffed hydrogen molecule, dissociated hydrogen atom, helium atom produced through the fusion process, and etc. Since these species have different effects on the edge plasmas, a precise measurement of their composition ratio is usuful to optimize divertor operation scenario. We have proposed the method to measure the atomic-molecular ratio of hydrogen plasmas [1]. We extend this to He-H mixture plasmas. In this research we propose the method to measure the gas-composition ratio of He, H and H_2 of the He-H mixture plasmas in divertor simulator MAP-II by using passive spectroscopy. Adopting the coronal model to the emissivity of the Fulcher-α band of molecular hydrogen, the total transition from $X^1\Sigma_g$ to $d^3\Pi_u$ state can be obtained from the branching ratios of the excitation and radiative decay considering the ro-vibrational distribution of $X^1\Sigma_g$.
A collisional radiative (CR) model is applied to the emissivity of the Balmer series of the hydrogen atom [2] and helium atom [3]. The emissivity of Balmer series is expressed as the summation of direct and dissociative excitation components, which are proportional to the density of hydrogen atom the density of hydrogen molecule, respectively. The emissivity of He I is also proportional to the density of helium atom in the quasi-steady state approximation where the effect of the meta-stable state is negligible.
From the ratio of each emissivities of H-He mixture plasmas measured in the same viewing chord using the same optical system, the composition ratio of H, H_2 and He can be obtained.
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P7-12

Development of Heat Flow Measurement using Thermal Probe Method in Divertor Simulator MAP-II

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The thermal probe method is a new plasma diagnostic for various plasma parameters such as negative ion density[1] and ion temperature[2]. In the thermal probe method the heat flow into a probe tip (Q) is measured as a function of the probe bias (V). Therefore, it is necessary to obtain the Q-V characteristic with high accuracy in order to deduce these plasma parameters reliably. Since the time resolution of the thermal probe is poor in nature because of the long transient time in thermal phenomena, it is essential to improve its time response. The goal of this study is the improvement of the accuracy and time resolution in the Q-V characteristic measurement.
The Q-V characteristic can be measured by two methods. One is to sweep the bias continuously and the other is to change it in a stepping manner. Although the former method can obtain a continuous Q-V curve, it requires long acquisition time. On the other hand, while the latter method saves acquisition time, only finite data points can be obtained. The comparison of the two methods was made with the low-pressure helium dc-arc discharges in the divertor simulator MAP-II. The preliminary results showed a small difference in Q-V characteristic obtained by two methods. The optimization of the sweeping method as well as the fitting procedure for analysis is now under investigation.
This work was supported in part by a NIFS Collaborative Research Program (NIFS04KOAB009) directed by the second author.

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P7-13

Development of a neutron measurement system for nd/nt fuel ratio measurement in burning plasma

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For burning control experiments in the International Thermonuclear Experimental Reactor (ITER), it is essential to measure the deuteron and triton density ratio in the core plasma. We consider that it can be achieved by measurement of DT/DD reaction ratio. The possibility of measurement of fuel ratio from the DT/DD reaction ratio with a neutron spectrometer to the ITER was studied. Spectrum in the DD neutron energy region is usually contaminated by the scattered/energy-degraded neutron background originating from DT. Here, We assessed scattered/energy-degraded neutrons by Monte Carlo N-Particle code system (MCNP). The result of neutron transport calculation indicated the possibility of DD spectrum separation from the scattered/energy-degraded neutrons derived from DT neutrons by selection of the measurement location and collimator design. And a measurement method was considered. It is required that each neutron is measured separately and simultaneously. In order to realize this technique, an examination of a measuring instrument and a circuit was performed. A double crystal time-of-flight (TOF) spectrometer was chosen because the spectrometer is relatively compact, not affected from a magnetic field and provides real-time information. We propose a method for rapid selection of DD and DT events using multi-discriminator electronics for the first detector. An experiment using DD and DT neutrons from an accelerator was conducted for a proto-type TOF spectrometer at the Japan Atomic Energy Agency (JAEA), Fusion Neutronics Source (FNS) facility. Using a sophisticated circuit with discriminators for the first detector, separation between DD and DT neutron components of spectrum was achieved.

P7-14

Neutron spectral broadening due to the polyethylene collimator of the fast neutron spectrometer

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Neutron spectrometry is an important tool in several fields such as fusion plasma diagnostics and nuclear physics. We developed a fast neutron spectrometer with excellent energy resolution and good detection efficiency [1]. The spectrometer consists of three position-sensitive proportional counters (PSPCs) with methane gas and two Si(Li) surface barrier detectors (Si(Li)-SBDs). Incident neutrons through a collimator made of polyethylene and lead interact hydrogen atoms to generate recoil protons. The energy and recoil angles of the protons are simultaneously measured with the PSPCs and the Si(Li)-SBD. Finally, we can obtain the neutron spectrum with the energy resolution better than 2 % for 5.0 MeV neutrons. However, the neutron spectrum might be broadened by (1) the scattering of neutrons in the polyethylene collimator and (2) the non-parallel incident of neutrons that is amplified with the ratio of a diameter of the collimator to a distance from a neutron source.
In the present study, a new simulation code MCNP-ANTX was developed by modifying the MCNP4C code [2] in order to investigate the effect of spectral broadening. The MCNP-ANTX code includes a new tally subroutine with the TRIM-98 and SRIM-98 codes to simulate the transport of accelerated ions, generated neutrons and charged particles produced in neutron detectors. The MCNP-ANTX was applied for the simulation of the behavior of neutrons and recoil protons in the spectrometer. The results of the simulations are compared with those obtained from experiments using monoenergetic fast neutrons in this presentation.

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P7-15

Characteristic observation of the ion beams in the plasma focus device

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The proton emission from plasma focus device with the H2 filling was analyzed. The ion beam characteristics, particle pinhole image and pinch plasma image were obtained with an aluminum filtered pinhole camera with CR-39 film and x-ray pinhole camera with Be filter respectively. Ring-shaped of ion bunches were observed and also on the pinched plasma column same shape was attributed.

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P7-16

Development of a Simple and Tough Alpha-particle Detector Used at High Temperature

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The response of some ceramic ($Si0_2$, Al_2O_3, etc.) and compound semiconductor (SiC, CdTe, etc.) materials to energetic ions has been examined for the development of a tough alpha-particle detector used at high temperature. To measure the electrical response of the materials, very thin silver electrodes were made on both sides of the thin sample materials by evaporation process. The thin high-resistive layer of each sample material was irradiated with alpha-rays from an ^{241}Am source or pulsed ion beams from an accelerator and the induced electric charge on the sample was measured in the temperature range from room temperature up to 450K. Corresponding charge pulses could be detected for samples with the proper electric field, though the amplitude of the pulses varied widely. This type of the simple detector made of a thin resistive layer can be hardly used for the energy analysis, but it may be effectively applicable to the measurement of the flux of alpha-particles at high temperature. Detailed measurement results and discussions on the response of the ceramic and compound semiconductor materials to alpha-particles are to be given in the conference.

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P7-17

Effects of ion orbits due to potential formation on transverse ion transport in the thermal barrier region of GAMMA10

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A mechanism of a transverse ion loss in the thermal barrier region of the GAMMA10 tandem mirror is investigated by the use of mapping equations of ion drift orbits, where the effects of a non-axisymmetric electrostatic potential in the thermal barrier are taken into account.
Two sorts of the mechanisms of the transverse ion transport in the thermal barrier are studied. First of all, the enhanced effects of the transverse diffusion on ion radial step sizes is investigated, since banana-like ion drift orbits appear on the basis of the non-axisymmetric electrostatic potential formation. Secondly, chaotic ion orbits due to unstable ion drift are found, which result in cross-field ion diffusion without Coulomb collisions. For the first mechanism, we use the secular perturbation theory to estimate the half width of the banana orbits, and compare the results with those from the numerical calculations. For the second mechanism, we use the continued-fraction method to find the threshold of the magnitude of electrostatic non-axisymmetricity, where the ion drift orbits become unstable. The resultant transverse transport is analyzed by using the Fokker-Planck theory. The result is compared with that from the mapping equation method.
The aforementioned theoretical results as well as the relation between the ion radial transport and electrostatic anisotropy in the GAMMA10 thermal barrier region are detailed at the Conference.

P7-18

The Neutral Transport Analysis Based on Visible Light Measurement of Recycling and 3-dimensional Simulation in GAMMA 10

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In the GAMMA10 tandem mirror, H_α line detectors are installed on the various places. H_α emission from plasma gives the information on neutral densities. Neutral particle provided by wall recycling and/or gas puffing is an important factor for investigations of particles balances, plasma-wall interactions, plasma fueling and so on [1]. Electron cyclotron heating (ECH) are applied in the central and plug/barrier cells. These are used for producing hot electrons and plasma confining potentials.
In the initial period of the experiments, the plasma diamagnetic signals in the central cell remarkably decrease simultaneously with applying ECH in the central cell (CECH). At the same time, H_α line intensity increases particularly near the central mid-plane. After the considerable number of plasma discharges, however, the plasma diamagnetism increase even during CECH, where it is found that almost no appreciable changes in H_α line intensity are observed in the central cell. Recently, from visible light measurements by using high-speed cameras [2], the intense emission from the central limiter is confirmed when plasma diamagnetism decreases during CECH. Therefore, the intense emission is closely related to the degradation of the plasma performance.
A Monte-Carlo simulation code (DEGAS) is applied for the purpose of the neutral transport analysis [3, 4]. In the mesh model designed for the present simulation, the inner structures of the vessel wall including the central limiter are precisely implemented. By using this model, neutral transport simulation including the effects of such source hydrogen from a limiter has been carried out for the first time. In this paper, the recycling source term is quantitatively evaluated from the result of DEGAS simulation and the calculation results are compared with the experimental results. The relationship between the limiter and the plasma during CECH and gas puffing will be discussed.

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P7-19

Calculation of Fusion Condition of Hydrogen-Boron by I.C.F Method

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In order to arrive to clean and energy efficiency, the advantages of using advanced fuels for fusion have been recognized for a number of years, safety and environmental issues are two important problems.
In order to avoid the radioactive tritium and undesired radioactivity induced by the generated neutrons (most will be used for breeding tritium in lithium surrounding the reaction and absorbing most of the neutrons), the very clean nuclear fusion reaction are Hydrogen - Boron.
In this paper D-T fusion, H-B fusion theoretically are studied and calculated by computer simulation with ICF method, the results are comparable with the experimental data.
In this computation the following cases are considered: Primary ionization and heating by laser, secondary heating and compressing by laser, and the reabsorbing of Bremsstrahlung and a-particles (they cause self-heating of the plasma)
Calculations have two parts: calculating of optimum gain in input energy and calculating of plasma temperature in the confinement time.
In this work it was seen the necessary input energy for H-B fusion is very much (GJ range) the results show that we can used to the output energy provided by D-T fusion for H-B fusion with adding a small D-T core in H-B fuel.
Details and results will be discussed in full paper.

P8-01

Sheath Structure around Negatively Biased Probe in Electronegative Plasma

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Langmuir probe method is widely used to determine plasma parameters such as electron temperature. It is based upon measuring the current onto a probe as a function of the probe voltage. Recently, new type probes, which measure momentum flux (Combined force-Mach-Langmuir probe[1]) or heat flux (thermal probe[2]), have been proposed. Since these flux are dependent upon sheath potential structure, precise knowledge on the sheath around biased probes is indispensable.

Recently, the effect of negative ions on the sheath potential structure has been studied by using Berkeley code(XOOPIC). [3] By changing electrons with hydrogen negative ions, the simulation becomes unstable and numbers of hydrogen positive/ negative ion in the calculation geometry oscillates with time much slower than plasma oscillation period.

We confirmed the XOOPIC results of stable electropositive plasma by comparison with steady state solution of 1D collisionless Boltzmann equation. Then, we observed ion distribution function for unstable electronegative plasma. As there exist beam components in distribution function of electronegative plasma, a kind of two stream instability may occur. Detail discussion will be given at the conference.

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P8-02

Development of ITER diagnostic upper port plug

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A diagnostic device in ITER is planed to integrate in the “port plug”, which serves both as the neutron shield and enables diagnostics to access to the plasma in the severe radiation circumstances of ITER. Only basic concept has been given for the port plug so far. In this work, the integration design of port plug including for manufacturing has been performed for the No.11 upper port plug, which would be procured by Japan.
The upper port plug structure should have enough margin of stiffness since the port plug is cantilevered structure with length of ~6 m and weight of ~22 t. To achieve such large stiffness, the upper port plug is designed to compose of forging material with thickness of 70 mm. To reduce the manufacturing cost, the commercial base material such as rolling material with thickness of 40mm was considered. The second moment of area and strains were calculated to evaluate the combination of rolling material and the lib structure. As a result, this structure can be achieved as the same stiffness as the present design.
Three diagnostics will be installed in the No.11 upper port plug, i.e., the edge Thomson scattering system, the visible-IR TV divertor viewing system and the neutron activation system. To integrate theses diagnostic systems in the port plug, the labyrinth of optical path, the driving and cooling systems for shutters and mirrors, the maintenance space and the interaction of each other were considered. A space just behind the blanket shield module (BSM) was changed to use as a space for maintenance and for layout of associated diagnostic first mirror and shutter, whereas this place was assigned for neutron shielding. The neutron shield module in this space was moved in front of flange instead. The structure and the position of the BSM support, which is main component inducing the electro-magnetic load, have been arranged to secure the optical path inside BSM. Three-dimensional model of partial vacuum vessel, port and blanket module, located around the port plug, was constructed for the electro-magnetic analysis. The upward fast VDE was selected to calculate the EM loads because it produces the most severe load for the upper port plug. As a result, maximum moment at the port flange was about 1 MNm, which is within the design guideline of the port plug.

P8-04

Advanced Probe Measurement System in TU-Heliac

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In H-mode of tokamaks, formation of the radial electric field and the poloidal flow, decrease of H_α emission have been observed. The improvement of the confinement accompanied with these observations. Improved modes have been also observed in helical systems such as CHS, LHD, etc. The reduction of the transport in the improved modes is suggested that the radial electric field is formed and the anomalous transport is reduced by ExB flow or flow shear.
An electrode biasing is recognized as a very powerful tool to control the radial electric field and a supersonic poloidal flow. Thus in the TU-Heliac, negative biasing experiments using a LaB_6 hot-cathode have been carried out. During biasing, formation of the radial electric field, increase of the electron line density, decrease of the density outside the last closed flux surface have been observed. Poloidal Mach number exceeded unity and reached 5 (supersonic regime).
Density and potential fluctuation measurements are important to estimate the anomalous transport. Langmuir probe method is useful for the fluctuation measurement in low temperature plasmas. Ion saturation current fluctuation, which corresponded to density fluctuation, was measured in biased plasma. The fluctuation was suppressed in the frequency range less than 100 kHz. On the other hand, the fluctuation was increased in the region ~200 kHz. Langmuir probes for the floating potential fluctuation measurement were designed and applied in supersonic flow plasma.

P8-05

Mach Probe Measurements of Detached Plasmas in a Linear Plasma Device

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Detached recombining plasmas have attracted great interest from the point of view of handling of plasma heat flow in the divertor of magnetic confinement fusion experimental reactors. It makes a strong temperature gradient along the magnetic field. Recently, the importance of plasma flow for the formation of detached plasma has arisen [1, 2]. Plasma flow along magnetic field lines is an essential general issue and of particular importance for the proper functioning of the divertor. In particular, detailed and careful measurement of plasma flow in detached region is needed. However, there are some difficulty for flow measurement in that region because of low temperature and the limited accessibility so on.
In this study, we have attempted to measure the plasma flow velocity in detached plasma in our linear plasma device by using Mach probes. In reference 3, a strong anomaly of the single Langmuir probe characteristics was reported in detached recombining plasmas, where the conventional analysis of the probe characteristics gives us a considerably high electron temperature compared with the value determined with the spectroscopic methods and proposed choosing suitable reference electrode or double probe for measuring detached plasma. Therefore, we must use probes with attention in detached plasmas. So that reason, in this study, using Mach probe consisted of two set of double probe for avoiding the uncertainty, we investigate the change of the flow pattern of attached to detached plasmas and discuss the influence of plasma flow on the plasma detachment.

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P8-06

Measurement of Electron Density and Temperature and Their Fluctuations Using a Triple Langmuir Probe Grounded through Finite Resistance

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In the triple Langmuir probe method, the electron temperature (T_e) is derived on the assumption that the current is not drawn from plasma through a potential measurement circuit and the electron density (n_e) is derived from the ion saturation current (I_{is}). In the case of aiming at measuring high-frequency fluctuations, however, the smaller the load resistance in a potential measurement circuit is, the better the frequency characteristics are. Then the finite current flows in the circuit of measurement of the floating potential (V_f) and the plus-biased potential (V_p). Recently, we are performing a simulation experiment of plasma transport in high temperature and density plasma using low temperature and density one. In the low temperature and density plasma of the $n_e <\sim 5\times10^{17}$ m^{-3} and $T_e < 30$ eV, the current of the circuit of V_f and V_p become comparable to the measured I_{is}. In this situation, the effect of finite currents in V_f and V_p measurement circuits should be taken into account in order to derive T_e using the triple probe data. We have derived a modified expression to derive T_e from the probe data here the finite current in the circuits of the V_f and V_p, and confirmed the applicability of the expression experimentally.

P8-07

Calibration of Fast Ion Flux Measured by a Directional Probe

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Fast ion confinement is one of the most important key issues for burning plasmas, such as, ITER. Significant enhancement due to MHD activities, such as, toroidicity-induced Alfven eigenmodes (TAE), energetic particle modes (EPM) were observed in many devices, and strongly studied both experimentally and theoretically. In order to observe fast ion behaviors associated with MHD activities, a directional Langmuir probe method was applied for plasma heated by neutral beam in CHS, and observed fast ion behaviors synchronized with MHD activities. A directional probe can measure local behavior of fast ions with high time resolution. On the other hand, absolute value of fast ion flux is difficult because of secondary electron emission from probe surface.
In order to evaluate secondary electron effect, an experimental calibration of the probe method was performed using beam produced by (neutral beam injector) NBI. The neutral beam and a mixture beam of neutrals and residual ions were irradiated to the probe, and the beam currents and secondary electron currents were measured. The secondary electron emission efficiencies were obtained against neutral beam and ion beam. The efficiency for ion beam is sensitive to the beam energy, though that for neutral beam has little energy dependence in the energy region of 20 keV to 35 keV.

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P8-08

Probing of toroidal electron plasmas confined in CHS magnetic surfaces

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This paper describes the details on the probing applied to helical electron plasmas having low density n_e and large negative space potential φ_s.

Since 1923, the Langmuir probe has been used for measuring plasma particle flux Γ and φ_s. Even at present, it is employed for various plasma experiments on such as basic plasma physics and peripheral layer of fusion plasmas. Although various types of the probe have been developed, the typical bias voltage V_p is at most in the range between -100 and +100 V. However, when we apply the probing to toroidal pure electron plasmas, V_p needs to be much higher because of the large value of φ_s. For example, typical values of φ_s of helical electron plasmas on CHS is down to about – 1 kV. This result requires that V_p must be swept down to about −1.5 kV or less in order to obtain current-voltage (I-V) characteristics. Also, since there are ideally no ions, the I-V characteristic is completely different from that of neutral plasmas. In addition, assuming that electron temperature T_e is ~ 100 eV of helical electron plasmas, the electron Debye length λ_D is calculated to be ~ 7.5 cm for $n_e \sim 10^{12}$ m^{-3}, which is comparable to the plasma characteristic length (10 cm). In this case, the I-V characteristic is expected to an orbital motion limited regime. Finally, the electron plasmas possess fast E×B flow, so that the obtained I-V characteristic would spread more, showing non-Maxwellian distribution as well as those observed in space plasmas.

In this research, with details of the probing system especially for the helical electron plasmas confined in CHS magnetic surfaces, we discuss the probing for plasmas with large φ_s and low n_e. In the developed electronics, a differential circuit using an instrumentation amplifier (INA111) is employed. And, in order to accurately set the differential input resistance, a trimmer (500 Ω) is installed between the two input terminals. Since n_e of the plasmas is relatively low, the measured I becomes smaller. Thus, in the feedback resistors of the circuit, the trick of a T-network is applied to reduce the effect of thermal noise from the resistors. With regard to the measurement of φ_s, a high voltage probe (Tektronix P6015A) with an output impedance of 47Ω is employed. The reference potential of the circuit is grounded across a low resistor (100 Ω), which can cancel the significant ground loop voltage arising around large devices such as CHS. Typical data are also presented.

P8−09

Technique of MHD mode analysis using magnetic measurements in heliotron plasmas

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Identification of low-n MHD instability is important to understand characteristics of the mode and its effect on plasma confinement, and its analysis technique by using magnetic sensors such as probes and flux loops has been established through long-term experiments in various magnetic confinement devices. The recent fusion devices have complex shape of plasma cross-section compared with conventional machines and a spatial limitation to an installation of magnetic sensors, whereas the accurate measurements of Fourier components of magnetic perturbations are required as before. In the case of the heliotrons with non-axial configuration, the magnetic field lines have ripples due to the field period of helical coils, which makes an identification of the mode structure difficult as well as toroidal effects even if magnetic sensors are installed at ideal locations. Therefore, in Large Helical Device (LHD), the multi-filaments are put along the specific magnetic field line on the Boozer coordinate, and magnetic field and flux at sensor position are estimated for identifying spatial mode structure. The 3-D MHD equilibrium code VMEC was used for transformation to Boozer coordinate. This technique can be applied to finite-beta plasmas with large Shafranov shift. Since the LHD has several low-order rational surfaces in the periphery with magnetic hill, pressure-driven modes excited there have been well observed in finite beta plasmas [1,2]. In order to verify the validity of the mode identification, the experiment for controlling the peripheral pressure gradient was done by inserting the pump limiter [3]. As the results, MHD modes disappeared one after another with inserting the limiter, and it has been found out that their disappearances are consistent with reduction of pressure gradient on each resonant surface.

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P8-10

Magnetic Diagnostics of Magnetic Island in LHD

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Characteristics of magnetic islands are investigated measuring by the magnetic diagnostics in the Large Helical Device (LHD). The magnetic island enlarges or shrinks during a plasma discharge without any active controls, which is observed by the change of the local flattening shape of the electron temperature profile measured with the Thomson scattering. However, that profile can be obtained at only one toroidal position and therefore gives limited knowledge of the structure of the island. On the other hand, the structure of the magnetic island can be estimated from measuring the perturbed magnetic field appearing when a magnetic island changes. To measure the toroidal profile of the perturbed magnetic field $\delta b(\varphi)$ originated from the plasma, the toroidal array of 5 magnetic flux loops is set at the outer ports in the LHD. The amplitude and the Fourier component of the toroidal profile of the $\delta b(\varphi)$ correspond to the width and the toroidal mode number of the magnetic island. Also, the phase of the toroidal profile of the $\delta b(\varphi)$ which corresponds to the toroidal position of the X-point of the magnetic island can be estimated. When the seed island produced by the externally imposed static error field exists, the enlargement of the width of the magnetic island and the increase of the $\delta b(\varphi)$ are observed. At the same time, the phase of the toroidal profile of the $\delta b(\varphi)$ and the static error field is almost the same.

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P8-11

Current Profile Dependence of CCS Method to Reproduce Spherical Tokamak Plasma Shape

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From the viewpoint of plasma control, plasma shape reproduction in tokamak is very important, especially for the non-circular and triangular plasmas. The Compact PWI experimental Device (CPD) is a new small Spherical Tokamak (ST) in Kyushu University. Compared with the conventional tokamaks, ST has high natural elongation and natural triangularity, and the equilibrium and stability properties are much different because of the much smaller aspect ratio. As for a divertor configuration, the X-point and neutral line control is also important.

The Cauchy-Condition Surface (CCS) method is a kind of numerical method to reproduce plasma shape with magnetic measurement [1]. With the magnetic sensors, the flux distribution and plasma shape can be calculated. The CCS method will be adopted in the real-time plasma control and shape displaying of CPD. It can reproduce plasma shape of spherical tokamak in good precision solely with the measurements of flux loops or magnetic sensors [2]. In case of much elongated and triangular plasmas in spherical tokamak, good precision can be achieved by increase in degrees of parametric freedom representing the Cauchy condition.

There are various kinds of plasma current profiles in the discharge experiments. In order to control plasma shape precisely in real-time, the current profile dependence of CCS method to reproduce ST plasma shape will be studied. Firstly, various ideal flux surfaces corresponded to different plasma profiles are made by equilibrium code. Secondly, these plasma shapes are reproduced by using CCS method. Thirdly, the original and reproduced shapes are compared. The current profile dependence will be described in detail.

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P8-12

Two-dimensional edge density measurements in the Large Helical Device

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The edge plasma has been considered to affect the overall energy and particle confinement in fusion test devices such as tokamaks and stellarators, since the formation of the transport barrier, excitation of turbulent fluctuation, edge localized modes, ELMs, blobs, etc. are taken place in this region. Recently it has been known that such phenomena do not always appear symmetrically in toroidal and/or poloidal directions. Thus the one-point or one-dimensional (1D) measurement by using e.g. a conventional Langmuir probe is not sufficient to know the overall picture of the phenomena. For the physical understanding, the two-dimensional (2D) imaging system must be needed, and be helpful.
We have developed a sheet-shaped thermal lithium beam probe (LiBP) to measure electron density profiles two-dimensionally with high time and spatial resolutions. With the diagnostics, 2D-emission distributions of Li resonance line (670.8nm) at the poloidal cross section have successfully been observed by using a CCD camera, and 2D-density profiles have also been acquired with the beam attenuation method. Recently, density fluctuation measurement at several points on the poloidal plane has started, and preliminary results have been obtained with various discharges in the Large Helical Device (LHD).
At the conference, the performance of the 2D-beam itself and validity of the reconstruction method for fast phenomena are also discussed.

P8-13

Measurement of 3-D Mode Structure of the Edge Harmonic Oscillations in CHS using Beam Emission Spectroscopy

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A coherent magnetohydrodinamic (MHD) mode which has characteristics similar to those of the edge harmonic oscillation (EHO) in the quiescent H-mode of tokamaks [1] has been observed in the compact helical system (CHS) [2], which is a low-aspect-ratio, middle size heliotron (major radius = 1 m, minor radius = 0.2 m, toroidal period number = 8, poloidal mode number = 2) in the discharges with the edge transport barrier (ETB) [3]. EHO in CHS has the fundamental frequency of 3 - 5 kHz and its second and third harmonics. It has a peak amplitude at approximately the normalized minor radius $\rho = 0.95$.
In the present study, the spatial structure such as correlation, wavenumber, and propagation of EHO in CHS is investigated using the beam emission spectroscopy (BES) and the magnetic probe array. BES has been developed in CHS to simultaneously measure both local density fluctuations and gradients [4]. It detects emissions from the neutral beam atoms which are excited through collisions with bulk plasmas. The hydrogen neutral beam for heating with the acceleration voltage of about 32 keV is used for the probe beam. The avalanche photo-diode detectors combined with a 100 kHz low-pass filter are used as photon detectors. Since the observable region is the intersection of the beam line and the sightline, local values and their correlations can be obtained. The viewing chords used in BES consist of an array of 16 optical fibers with an object lens. One can select the arrangement of the fibers in radial or poloidal direction to measure radial or poloidal structure of the fluctuations. Magnetic probe array is also used to measure both poloidal and toroidal structure. NIFS Collaborative Research Program (NIFS02KZPD003).

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P8-14

Potential measurement with 6 MeV Heavy Ion Beam Probe on LHD

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In a helical configuration of toroidal magnetic field confinement system, the electric field plays an important role on its neoclassical transport. Moreover, it is predicted theoretically that shear of electric field makes correlation length of turbulence in plasma shorter, by which the reduction of the anomalous transport is achieved.
A heavy ion beam probe (HIBP) is a diagnostic tool to measure the potential directly in the interior of high temperature plasma with good spatial/temporal resolution. Therefore, it is a very useful tool to study above subjects, namely, the relation between electric field and confinement experimentally. In Large Helical Device, HIBP system, of which probing beam is 6 MeV Au^+, was installed and has been developed.
In this system, the beam of Au^- produced by the plasma-sputter ion source is injected to the tandem accelerator, and in a gas cell at the center of accelerator the charges are stripped so that Au^+ beam is produced. Au^+ beam is transferred to LHD plasma through several components of beam line, such as 4.8m cylindrical deflector, 7.8 degree deflector, 8 pole sweeper. In the plasma, Au^+ beam is stripped electron and transformed to doubly charged beam, Au^{2+}, mainly by electron impact, and this beam is guided to the tandem energy analyzer by another 8 pole sweeper located at the exit port. To detect a very small amount of current of Au^{2+} beam, we use the high gain current detector, MCP(micro channel plate).
The recent improved points of our system are as follows: Electric plates of 7.8 degree deflector are modified. By this modification, the occurrence of discharge between electric plates on the condition of high magnetic field (>2.8T) can be suppressed successfully. The new ion source that has larger size of target plate and plasma volume is made and tested. In the test stand, obtained Au^- current is 5 times larger than that from the previous one. Into the gas cell, a circulating system using turbo molecular pump is installed. Compared with the case of w/o circulating system, the fraction of Au^+ becomes two times larger. Many monitoring system are installed to check the small change in voltage and current of many voltage supplies for steerers, Q-lenses, deflectors. The change in the tandem accelerator voltage is also monitored. These monitoring systems will make our potential measurements more reliable. We will report the results of beam-orbit calibration and potential measurements in plasma in detail.

P8-15

Estimate of ionization cross sections for a heavy ion beam probe

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A heavy ion beam probe (HIBP) system has been installed in the Large Helical Device (LHD) at NIFS to measure the local plasma potential and fluctuation. The accelerated Au^- beam undergoes double charge exchange and the resulting Au^+ beam (primary beam), which normally reaches up to 6 MeV, is injected into the LHD plasma. The ionized beam (secondary beam : Au^{2+}) with a trajectory in plasmas is detected by the energy analyzer. The local potential is obtained from the signals of the energy analyzer.
The ratio of primary beam current to secondary beam current is predicted by taking into account the beam attenuation in LHD. [1] They uses the ionization cross sections for Au^+ and Au^{2+} as a substitute for those obtained by the empirical formulae. Using the experimental signals of primary and secondary beams, which have recently been measured successfully in LHD, the validity of ionization cross sections is discussed. These ionization cross sections are essential to the reconstruction of electron density profiles from the primary and the secondary beam signals.

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P8-17

Structure of sample volumes of the heavy ion beam probe in LHD

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The heavy ion beam probe (HIBP) is a unique tool to measure the electrostatic potential and density fluctuation in high temperature plasmas directly and simultaneously. We have installed an HIBP in the Large Helical Device (LHD)[1], and recently it was verified that the HIBP could measure the potential in the plasmas [2][3].
One of the interesting phenomena in magnetically confined plasmas is the transition of radial electric field (Er). For example, a drastic change in Er is observed in local area during the formation of the internal transport barrier (ITB) in the LHD. In order to study such local transition phenomena, the appropriate spatial resolution is required.
In HIBPs, the detected beam comes from a finite volume which is determined by the width of the injected beam and the opening of the slit in front of the energy analyzer. It is referred to as the sample volume. The size of the sample volume determines the spatial resolution of the HIBP. Thus, the estimation and the control of the structure of the sample volume are important.
The sample volume is estimated by the trajectory calculation. Assuming an initially parallel, circular cross-section beam with 2 mm diameter, which is measured at the injection port to the LHD, the shape of the sample volume becomes an elongated ellipse, and the largest dimension is about 25 mm when the sample volume is located at the center of the plasma. This spatial resolution is sufficient to measure the change in the potential profile during the formation of ITB probably, though it may be inadequate to measure micro-instabilities.
In the presentation, the effect of the emittance and the energy spread of the probing beam will be shown, and the optimization of the structure of the sample volume will be discussed.

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P8-18

Observation of the effects of radially sheared electric fields by the use of a gold neutral beam probe

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In the tandem mirror GAMMA 10, the electrostatic potentials have originally been produced in the plug and barrier regions so as to improve the confinement of central-cell ions and electrons, respectively. Recently, high power gyrotrons (28 GHz, 0.5 MW) significantly enhance the potential heights [1]. The advance in the potential formation gives bases for a finding of the remarkable effects of radially produced shear of electric fields dE_r/dr, or non-uniform sheared plasma rotation on the suppression of intermittent vortex-like turbulent fluctuations. Such a shear effect is visually highlighted by X-ray tomography diagnostics. During the application of plug electron-cyclotron heating (ECH), the produced stronger E_r shear results in disappearance of such intermittent turbulent vortices with plasma confinement improvement [1,2].
A Gold Neutral Beam Probe (GNBP) in the central cell is employed for measuring (1) profiles of radially formed potential as well as the associated radially sheared E_r in the central cell. (2) By the use of a capability of good time and energy resolution of the GNBP system for the present phenomena, potential fluctuations are also investigated from the viewpoint of finding the relation between E_r shear and the fluctuation suppression.

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P8-19

Beam Probe Imaging Method for Edge Plasma Modeling in CHS

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Edge magnetic field line structure outside the last closed flux surface (LCFS) in helical devices is generally chaotic and plasmas confined in the area are intrinsically three-dimensional. Field line mapping on a poloidal cross-section, which is often referred as Poincare plots, is a good index of a chaotic structure of the magnetic field outside the LCFS. Plasmas confined in the region cannot be described as a simple flux function as is done for core plasmas confined in closed flux surfaces. In order to study plasma structure and behavior in the chaotic region, two-dimensional diagnostic is essential. Direct comparison of two-dimensional plasma distribution with the chaotic field line mapping is a promising approach to understand the full three-dimensional plasma structure in the region, which is necessary for a practical helical divertor design in fusion reactors.

We have developed a neutral lithium beam probe (LiBP) with scannable beam injection angle in a poloidal cross section, which gives a two-dimensional plasma distribution in the edge and separatrix region. This is a kind of imaging diagnostic by the use of the beam probe method. The up-down asymmetry of the plasma structure is observed in the horizontally elongated poloidal cross-section, where the chaotic filed line structure shows up-down symmetry. The plasma asymmetry reverses when the magnetic filed direction reverses, suggesting that poloidal drift motion of plasma particles associated with field line non-uniformity plays a key for steady state plasma distribution in the region. Such asymmetry will be the source of non-uniform heat deposition on divertor plates observed several helical devices. Plasma structure and behavior in the ergodic layer, which is artificially applied for ELM stabilization, is also a growing concern in tokamaks. The beam probe imaging method will be useful for modeling of such plasmas.

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P8-20

Two dimensional Li beam imaging to study the magnetic field configuration effects on plasma confinement in spherical tokamak CPD

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Spherical Tokamak (ST) can suatain a high beta plasma in a compact shape of low aspect ratio and hence is considered to be the most economical fusion reactor concept. The possibilities of rapid current ramp up in ECH plasma with only 1-2 kA initial plasma current has been demonstrated in the small ST device LATE [1] in a weak mirror configuration. Such current rise in the presence of B_Z is considered to be responsible for the change of magnetic field topology from a open field equilibrium to a closed field equilibrium. Thus it is important to study the change in plasma confinement mechanism in various types of magnetic field configurations. Recently two dimensional Li beam imaging technique [2] has been used to study the topological effects of various magnetic field configurations on the plasma confinement during RF as well as ohmic phase in the spherical tokamak CPD.

CPD is a compact ST device (R_0 = 0.3 m, a_0 = 0.2 m) with central solenoid, four TF coils and three set of poloidal field coils. A set of 8.2 GHz Klystrons (8 × 25 kW, CW) is used to initiate the RF plasma and for ECH. In order to investigate plasma confinement topology under various magnetic field configurations and to obtain the density contour in the lower half of CPD plasma a 2D density imaging system is installed which is composed of a sheet thermal Li beam injector at the bottom of the chamber and a CCD camera equipped with an optical filter (670.8 ± 0.5 nm) at the lower half of midplane. 2D images of LiI resonance line (300 × 500 mm^2) are recorded with a time resolution of 1 ms and spatial resolution of ~1 mm. The performance of the sheet beam is absolutely calibrated by a quartz crystal monitor and the width and uniformity of the sheet beam are also confirmed.

Recent experimental results with RF plasma in magnetic null configuration and in the presence of B_Z are summarised as follows.

While a sharp lower boundary is found to exist for the RF plasma in magnetic null configuration, existence of such boundary in the presence of B_Z is found to depend on the decay index of B_Z inside the plasma volume. With a small negative decay index of B_Z no such boundary is observed, but boundary is found to exist with a positive decay index of B_Z. Overdense plasma formation is observed in all these cases. All these experimental results along with the results of plasma confinement in ohmic configuration and possible mechanism for overdense plasma formation will be discussed in this paper.

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P8-21

Numerical Simulation of a High-Brightness Lithium Ion Gun for a Zeeman Polarimetry on JT-60U

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Understanding of the structure of the edge pedestal region is one of the important issues for tokamaks. Particularly, the edge current density caused by a strong pressure gradient accompanied by H-mode affects magneto-hydrodynamic (MHD) stability and edge localized mode (ELM) [1]. Then a Zeeman polarimetry by use of a neutral lithium beam has been developed for the measurement of the edge current profile [2]. The Zeeman polarimetry can obtain the pitch angle of the magnetic field from a polarization angle of the Zeeman component of the Li 2S-2P line. Recently, the Li Zeeman polarimetry is planned on JT-60U, and a high-brightness ion gun is developed for the purpose of a good signal-to-noise ratio. For the achievement of high spatial and temporal resolutions, the performance of the ion gun is one of the important components.
The ion gun consists of an ion source, acceleration electrodes, an electron suppressing electrode, an einzel lens, XY sweepers, and a neutralizer. A 50 mm thermionic cathode of a porous tungsten disk with β-eucryptite is used for the high brightness ion source. The Li^+ beam is accelerated to 30 keV and neutralized by sodium vapor in the neutralizer. The beam current above 10 mA and the beam radius below 15 mm are expected for the good resolutions. However, the beam transport length of the neutral beam from the neutralizer to the plasma is about 5 m. Then, the requirement of a divergence angle is below 0.17 degrees.
The initial performance of the prototype ion gun is investigated by the numerical simulation including the space-charge effects. Child-Langmuir current of the ion gun is estimated to be about 30 mA, and the current density is about 15 A/m^2. The ion beam hit the anode due to spread caused by the space-charge effects. Therefore, the acceleration electrodes need to be considered to achieve the low beam loss, the high Child-Langmuir current and optimized focal length. The geometry of the einzel lens also needs to be optimized so as to focus and collimate the beam on the neutralizer, because the neutralized position is important parameter in order to obtain the low divergence angle. As a result, the policy of a new design of the high-brightness ion gun is obtained by the numerical simulation.

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P8-22

Proof of principle experiment of a fast He0 beam production for alpha particle diagnostics

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Alpha particles produced at 3.5 MeV by D-T reactions are important to sustain self-burning plasmas, and their properties such as spatial distributions and velocity distributions should be measured. In order to make alpha particles to escape from confined plasmas it's proposed that a $^3He^0$ beam is injected into plasmas and an alpha particle is neutralized by capturing two electrons from $^3He^0$. We estimated the energy of a $^3He^0$ beam to be about 1.7 MeV. This diagnostics method is one of candidate methods for ITER. [1] We are developing a small sized beam device for proof of principle experiment of this method. The energy of a produced neutral helium beam will be below 150 keV. The process of a fast He^0 beam production is following. A He^+ of 30 keV beam extracted from multicusp ion source at 15-30 keV enters into an alkali metal charge exchange cell, where we consider to use Lithium at the first run, and is charge exchanged to He^+, He^0 and He^- beams. By bending magnet, a He^+ beam is bended to 30 degree and detected by a calorimeter, a He^0 beam detected by a pyro electric detector and calorimeter at 0 degree, and a He^- beam is bended to 90 degree. A He^- beam is injected into an electrostatic accelerator and it's accelerated up to 180keV. A He^- ion becomes a He^0 by auto detachment during free flight in the tube. The beams obtained from this system have several properties to be studied. (1) A He^- beam produced at charge exchange cell has energy distributions because of energy losses by collision with Lithium gas in the cell. (2) According to Schlacter and Loyd, the maximum value of the calculated double charge exchange efficiency of a He^+ beam in Lithium is 0.5 %[2]. Because the experimental efficiency is different from calculated one, we have to measure it by detecting currents of every beams at downstream of the cell and an injected He^+ beams. (3) Fast He^0 particles obtained in the free flight tube have two electron states. One is $1s^2\ ^1S_0$ ground state by auto detachment and the other is $1s2s\ ^3S_1$ metastable state He^* by collisional detachment, which is undesired for the diagnostics. The ratio of He^* ($1s2s\ ^3S_1$) / He^0 ($1s^2\ ^1S_0$) should be studied by laser induced fluorescence or other methods.

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P8-23

Raman and Rayleigh Calibrations of the LHD YAG Thomson Scattering

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The LHD YAG Thomson scattering [1][2] has been applied successfully to the measurements of electron temperature profiles of LHD plasmas. For electron density measurements, absolute calibration is required, and some techniques have been proposed, Rayleigh and Raman calibrations. In previous experiments, we have applied Raman calibration to obtain reliable absolute calibration factors [3]. In this experiment, we tried Rayleigh calibration as well as Raman calibration.

Since Rayleigh scattering doesn't shift the wavelength, special wavelength channel for detecting unshifted Rayleigh scattered light must be equipped in polychrometors, and very careful measures to suppress strong stray light are required. These are disadvantages in Rayleigh calibration. Especially the latter will be a serious problem in many cases. We eliminated the difficulty as follows. Generally, Rayleigh scattering signal intensity is proportional to scattering cross section, gas density, and laser intensity, whereas stray signal is proportional to laser intensity only. Therefore, the stray light can be reduced by decreasing laser intensity. In the Rayleigh calibration, we decreased laser intensity by about 10^{-4}-10^{-5} (1-10 mJ/pulse). Even in such cases, necessary scattering signal intensity can be obtained easily because Rayleigh cross section is very large. It is noted that 20 polychrometors with a Rayleigh wavelength channel have been calibrated by both Rayleigh and Raman calibrations whereas the other 124 polychrometors without a special Rayleigh channel have been calibrated by only Raman calibration.

In the both Raman and Rayleigh calibrations, pure nitrogen gas was introduced into the LHD vacuum chamber up to 50 kPa. As expected, both of them show a clear linear gas density dependence. Absolute calibration factors for electron density measurements are directly determined from the gradients [3]. We have obtained reliable calibration factors from both Raman and Rayleigh calibrations in the LHD YAG Thomson scattering. Detailed results of the Raman and Rayleigh calibrations will be reported at the conference.

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P8-24

Improving the Thomson Scattering Diagnostic installed on the Large Helical Device

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A problem that we are now confronting in measuring electron temperature (Te) and density (ne) of high density plasmas with central ne > $10^{20}m^{-3*}$ using the Thomson scattering diagnostic installed on the Large Helical Device is the low confidence on the data validity. This problem arises from the super luminous plasma back/fore-ground radiation, which boosts the DC current on the avalanche photo diodes (APD), exceeding the linear operating regime. To solve this problem to a large extent, we first must monitor the DC-level of the APD's outputs during plasma discharge. For this, we newly installed a 1024ch-scanning ADC to monitor the APD’s outputs, which are supposed to change slowly. Instead of the presently-used scheme of adjusting APD's output signal sizes by reducing the aperture size on the light collection window, we are planning to adjust the high voltage applied on each APD so that it works in the linear operating region. For this scheme to be valid, we must precisely calibrate the spectrum-responsivity of each polychromator for each high-voltage-combination. This tremendously time-consuming task will be pursued efficiently by illuminating a chopped blackbody radiation with well-known radiation temperature on a white reflecting plate attached on the light collection window and the diffusely reflected light being analysed. This method will also enable inter-shot calibration of polychromators. Furthermore, a short pulse white light from a super-continuum generator is considered in the future for a real time (inter-laser-shot) calibration, which will raise the confidence on the data-validity even in the nonlinear operation regime of the APD.

P8-25

Development of 2-D Thomson Scattering Measurement Using Multiple Reflection and the Time-of-Flight of Laser Light

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Two-Dimensional Thomson Scattering Measurement (2-D TS) has been developed using multiple reflections and the time-flight of laser light. The Thomson scattering measurement has been widely used as the most precise and reliable plasma diagnostics for measuring T_e and density n_e [1]. The initial single point measurement has been upgraded to multipoint and its spatial resolution has been improved significantly using TV Thomson system, LIDAR Thomson system. A limited extension to 2-D TS measurement has been realized using multiple sets of laser devices and polychromators [2], but the system necessarily suffers from high cost, and wide space. For the TS-4 experiment whose main mission is merging ST plasma and magnetic reconnection, the 2-D profile of T_e and n_e are keys to understanding the causes and mechanism for (1) the electron heating of the magnetic reconnection and (2) high-βST formation at merging start-up. Our new cost-effective approaches to the upgraded 2-D Thomson scattering system are (1) the multiple reflections of a laser beam to cover the 2-D(r-z) plane of the plasma and (2) utilization of the time-of-flight of laser light to reduce the number of polychromators and detectors. We are now planning to increase the time delay by adjusting the length of the optical fiber between the collection lenses and polychromators [3].

In our preliminary system, we have already detected the multiple Rayleigh scattering lights from two adjacent measurement points by the APD detectors. In this system, the laser path length between nearest two points is about 15m, which corresponds the laser flight time of 50ns. Our preliminary results demonstrated the basic principle of 2-D (2×4 points) measurement of the Rayleigh scattering, leading us to construction of the new 2-D TS system.

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P8-26

Laser scattering measurement of the electron density fluctuations in CHS

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Anomalous transport plays a dominant role in plasma confinement in magnetic confinement fusion devices. Since fluctuations cause anomalous transports and degrade plasma confinement, the understanding of physical mechanisms for fluctuations is one of the important issues towards realization of fusion reactors. We examined specifically about the electron density fluctuations in the Compact Helical System (CHS).

We adopted an electromagnetic wave scattering method. The frequency and the amplitude of electron density fluctuations are extracted from the spectrum of the beat frequency (1 MHz). The wave number of electron density fluctuations is determined by the Bragg relation.

We designed a three channel measurement system. This system enables us to detect scattered light at three angles simultaneously. The measurement system uses hydrogen cyanide (HCN) laser (wavelength: 337 μm) as the light source and detects scattered light by the heterodyne technique. Heterodyne measurement system has an advantage of capability to discriminate the direction of propagation of fluctuations. This system utilizes a super rotating grating (SRG) as a frequency shifter for the heterodyne detection. The SRG makes it possible to realize high-frequency beat signal up to 1.45 MHz. This leads to the wide frequency range of fluctuations of the scattering measurement.

In this study the location of the scattering volume in CHS is in a plasma edge region at the outer side of torus. In this location sharp fluctuation peaks, which have harmonic components up to the fifth, were observed. The fluctuations propagate only in the outward direction. The amplitude of the second component is always the largest among harmonic components.

After injections of two neutral particle beams (NB) for plasma heating, Hα emission signal, which roughly indicates information on the particle flux into the plasma, decreases spontaneously. Then the density gradient in the plasma edge region becomes steeper and an edge transport barrier (ETB), which reduces the loss of particles from the plasma, is formed. Frequencies of fluctuations increase after NB injections. However, they are suppressed after the transition. This measurement result suggests the improvement of particle confinement with the edge transport barrier.

P8-27

Laser Thomson Scattering Measurements in Helium Recombining Plasmas in Divertor/Edge Simulator MAP-II and its Comparison with Spectroscopy

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Electron temperature and density measurements of Helium recombining plasmas are performed in the divertor/edge plasma simulator MAP-II [1], by means of Laser Thomson Scattering [2] (using a Nd:YAG Laser, a double monochromator and an ICCD detector) and optical emission spectroscopy (using a spectrometer and a CCD detector).
The recent upgrades of our LTS system (reduction of the level of stray light and reduction of the pass-band of the notch filter) allowed us to measure temperatures as low as 0.1 eV and to investigate Electron Ion Recombination (EIR) processes in He plasma.
Spatial profiles of electron temperature and density along the plasma column have been taken moving the plasma recombination “front” across the measuring point by controlling the neutral gas pressure from 80 to about 140 mtorr. The electron temperature measured by LTS monotonically decreased along the plasma column until the lowest measured temperature of 0.15 eV [3].
Spectroscopic analysis applying He I CR model [4] is in progress in order to better clarify the physical processes leading to the decrease in temperature and density and to compare the results obtained by the two diagnostics.
This work is supported in part by NIFS Collaborative Research Program (NIFS04KOAB009) directed by the second author.

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P8-28

Collective Thomson scattering for alpha-particle diagnostic in burning plasmas

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A diagnostic of fusion-generated alpha-particles is important to understand burning plasma physics, however, an effective measurement method has not yet been established. A collective Thomson scattering (CTS) diagnostic using carbon dioxide (CO_2) laser (wavelength 10.6 μm) is being developed to establish a diagnostic method of confined alpha-particles. To realize the CTS diagnostic, a high-repetition Transversely Excited Atmospheric (TEA) CO_2 has been developed[1]. In order to obtain single-mode output, which is needed for the CTS diagnostic, seed laser is injected to the cavity with an unstable resonator. Using this technique, output energy of 17 J with the frequency of 15 Hz has been achieved with single-mode output. These results give a prospect for the CTS diagnostic on International Thermonuclear Experimental Reactor (ITER), which requires energy of 20 J with the repetition rate of 40 Hz. To measure the scattered signal with a high-repetition rate during long period (~60 s), waveforms are collected and analyzed by digital oscilloscopes. Proof-of-principle test is being performed with the improved laser system on the JT-60U tokamak.

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P8-29

Sensitivity study for the optimization of the viewing chord arrangement of the ITER poloidal polarimeter

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The poloidal polarimeter will be installed in the International Thermonuclear Experimental Reactor (ITER) to measure the profile of the toroidal current (safety factor) in the core region. The far-infrared laser beams pass through the plasma are reflected back along the same path by retroreflectors. The Faraday rotation of the polarization plane of each beam, which is induced by the poloidal field inside the plasma, is detected. The equatorial port and the upper port are used for the beam injections and the detections of the Faraday rotation[1]. The number of viewing chords is restricted to about 15 channels because of the geometric capacity of port plugs. Therefore the design of optimum arrangements of the chords is necessary to achieve sufficiently high accuracy as much as possible. Since the optimum viewing chord arrangements have not been known yet, we have begun to study.

There are two steps to optimize the chord arrangement. First step is the sensitivity study of viewing chord signals to the toroidal current profiles, which is described in this presentation. Second step is the evaluation of the accuracy of the toroidal current profiles based on the Magnetohydrodynamic equilibrium reconstruction method. The chord arrangement patterns and the toroidal current profiles, which are evaluated on the second step, should be restricted based on the result of the first step because the evaluations of all cases are actually impossible.

It has been reported that the equatorial viewing chords passing near the plasma center are sensitive to the central safety factor in case of the positive shear[2]. In addition to this previous result, we have found two sensitivities which are (1) the upper center chords are sensitive to the change in the toroidal current profile due to the change in the beta value although the equatorial center chords are not sensitive, and (2) the combination of the equatorial central chords and the equatorial middle position chords is sensitive in the case of the negative shear. According to the above new sensitivities, the chord arrangement combinations and the toroidal current profiles which should be evaluated by the reconstruction calculation are obtained.

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P8-30

Bench testing of polarimeter with Si photo elastic modulator for short wavelength FIR laser

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A Far infrared (FIR) laser interferometer is indispensable for electron density measurement in magnetically confined fusion experimental devices. A CH_3OH laser (a wavelength of 119 μm) interferometer [1] works routinely in the Large Helical Devices (LHD). Fringe jump errors, however, are serious problems in a high density range. In order to improve the reliability, the CH_3OD laser (57 and 48 μm) has been developed [2, 3] because a beam bending effect ($\propto \lambda^2$) in a plasma, which causes fringe jump errors, is small due to the short wavelength. On the other hand, an ι profile can be evaluated by polarimetry based on the Faraday effect. We are designing a polari-interferometer with the CH_3OD laser conceptually. This system can also be adapted to large tokamaks including International Thermonuclear Experimental Reactor (ITER).
Some measurement method of the Faraday rotation has been demonstrated up to now. The polarimeter with a pair of photo elastic modulators (PEMs) has achieved high temporal and angle resolutions and long time stability [4, 5]. It also has good compatibility with an interferometer. Since there was no PEM for the FIR range so far, the new PEM for the CH_3OD laser is developed by HINDS instruments. It adopts a Si plate with the high resistivity (several kΩcm), which has high FIR transmissivity, as the photoelastic material. The measured maximum transmissivity without an anti-reflection coating is 60% for both 57 and 48 μm, which is enough for the bench testing. However, multi-reflection inside the Si plate is found to be significant due to high refractivity (3.43) of Si.
We performed bench testing of the polarimeter with the Si PEM. Since this is the first trial of the PEM for the FIR laser, the optical configuration with only one PEM is utilized. Although a deviation is found in a small rotation angle, the measured polarization angle increased with rotating the polarization of the incident beam. The reason of the deviation is speculated to be caused by additional modulation components due to the multi-reflection. This will be improved by the AR-coating on the Si plate.

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P8-31

Development of Short Wavelength Far-Infrared Lasers and Optical Elements for Plasma Diagnostics

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In the Large Helical Device (LHD), the electron density profile has been measured by a 13 channel 119-μm CH_3OH laser interferometer[1]. However, short-wavelength FIR lasers in the region of 40 - 70 μm are superior to the 119-μm laser and a 10-μm CO_2 laser from viewpoints of the plasma refraction and mechanical vibration effects and the fringe shift for the high density operation of the LHD and future plasma device such as the International Thermonuclear Experimental Reactor (ITER). We have developed a new two-color interferometer using 48- and 57-μm CH_3OD lasers which can oscillate simultaneously[2]. The present status of the development of the components (the laser and optical element) is present.
The intensification of 48- and 57-μm CH_3OD lasers pumped by 9R(8) CO_2 laser has been done and a total power of 2.4 W has been achieved[3]. The power level is estimated to be more than 1.6 w for the 57-μm laser, with maximum power of 0.8 W for the 48-μm laser. We have measured beam profiles of these lasers to obtain the beam intensity distribution and the beam divergence angle. In a FIR region, water vapor absorption in the atmosphere is large. The absorption for the 48- and 57-μm laser lines was not measured. Therefore we have measured the water vapor absorption. A transmitted laser beam after passing through a cell which filled water vapor has been detected by a pyroelectric detector. The attenuation has been measured. If the humidity is 5 % at 22°C(actual vapor density ρ=0.97 g/m^3), the absorption coefficients of the 48-μm laser and the 57-μm laser are about 0.060 m^{-1} and 0.031 m^{-1}, respectively.
In order to design windows of the plasma vessel and beam splitters in the interferometer, optical constants of materials are necessary. We have measured the refractive index and the absorption coefficient of a crystal quartz, a silicon with high resistivity, and a CVD diamond and the transmissivity and the reflectivity of a polyethylene seat, a Mylar film, and a metal mesh. We have compared these materials and have examined use as the windows and the beam splitters.

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P8-32

Effect of pressure and magnetic field on parameters of plasma in a DC cylindrical magnetron sputtering device

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The parameters of plasma in a DC cylindrical magnetron sputtering device have been measured under different conditions. In this study a DC cylindrical magnetron sputtering device was used. This system consists of two coaxial cylinders with 10 cm and 21 cm in radius and 72 cm in length. The cathode was edged. The inner one was cathode. A magnetic coil mounted around the outer cylinder generated a nearly uniform magnetic field up to 550 G. the region between two cylinders was evacuated by means of a mechanical and turbo-molecular pump up to 10 -6 torr. The magnetic filed and pressure play interparticles collision role and therefore the degree of ionization and plasma temperature changed. The profiles of plasma parameter are obtained in vertical and radial axis in active manner. The influences of variation of pressures and magnetic fields on the mentioned profiles are investigated. Result will be discussed in full paper.

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P13-01

Development of ITER diagnostic upper port plug

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A diagnostic device in ITER is planed to integrate in the “port plug”, which serves both as the neutron shield and enables diagnostics to access to the plasma in the severe radiation circumstances of ITER. Only basic concept has been given for the port plug so far. In this work, the integration design of port plug including for manufacturing has been performed for the No.11 upper port plug, which would be procured by Japan.
The upper port plug structure should have enough margin of stiffness since the port plug is cantilevered structure with length of ~6 m and weight of ~22 t. To achieve such large stiffness, the upper port plug is designed to compose of forging material with thickness of 70 mm. To reduce the manufacturing cost, the commercial base material such as rolling material with thickness of 40mm was considered. The second moment of area and strains were calculated to evaluate the combination of rolling material and the lib structure. As a result, this structure can be achieved as the same stiffness as the present design.
Three diagnostics will be installed in the No.11 upper port plug, i.e., the edge Thomson scattering system, the visible-IR TV divertor viewing system and the neutron activation system. To integrate theses diagnostic systems in the port plug, the labyrinth of optical path, the driving and cooling systems for shutters and mirrors, the maintenance space and the interaction of each other were considered. A space just behind the blanket shield module (BSM) was changed to use as a space for maintenance and for layout of associated diagnostic first mirror and shutter, whereas this place was assigned for neutron shielding. The neutron shield module in this space was moved in front of flange instead. The structure and the position of the BSM support, which is main component inducing the electro-magnetic load, have been arranged to secure the optical path inside BSM.
Three-dimensional model of partial vacuum vessel, port and blanket module, located around the port plug, was constructed for the electro-magnetic analysis. The upward fast VDE was selected to calculate the EM loads because it produces the most severe load for the upper port plug. As a result, maximum moment at the port flange was about 1 MNm, which is within the design guideline of the port plug.

P13-02

ECR heating and ECE diagnostic in W7-X stellarator: ray tracing simulations of non-thermal effects

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The new ray tracing code was developed for electron cyclotron (EC) studies in arbitrary 3D magnetic configurations, with emphasis on heating, current drive (CD) and diagnostic of the W7-X stellarator (under construction in Greifswald, Germany).
The advanced Tokman-Westerhof model of the Hamiltonian is adopted for the ray tracing. This accounts for anomalous dispersion in the vicinity of the EC resonance. In turn, the cold, warm non-relativistic or weakly relativistic dielectric tensor can be used in the Hamiltonian, depending on which model applies. Finally, absorption and emissivity are calculated from the anti-Hermitian part of the fully relativistic dielectric tensor. Wave-particle interaction is modelled separately for passing and trapped electrons, the results are also plotted separately and combined in macroscopic quantities such as the deposition profile. This approach provides a better understanding of trapped particle effects on heating, emission, and CD in stellarators, not only in interpreting the experiments but also in preparing suitable plasma targets and magnetic configurations. The last tool is very useful for stellarator-specific problems,where the different classes of electrons have to be taken into account. The electron distribution used for absorption and emissivity calculations can be Maxwellian, bi-Maxwellian or arbitrary, thus allowing future coupling with a Fokker-Planck solver. At present, the adjoint approach is used for the CD efficiency calculations. The code can be used through a specially designed graphical user interface program, which allows preparation of input parameters and presenting the results of simulations in convenient form. The code is now routinely exploited in modelling heating and CD at various harmonics of the ordinary and extraordinary mode (O1, O2, X2 and X3) in different magnetic configurations. Similarly, EC emission spectra collected from the low or high field side of the machine in different poloidal sections are easily contrasted and might be used to diagnose fast electrons. The code is also supporting the design of some ECRH components for W7-X.

P13-03

Carbon redeposition under high-flux, low-energy ion irradiation effects on properties of tungsten films

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Carbon redeposition under high-flux, low-energy ion irradiation effects on properties of tungsten films will be reported.

P13-04

An exact linear dispersion relation for CRM instability

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An exact and self-consistent linear dispersion relation of a large orbit electron beam including two principles of cyclotron emission with oscillation frequencies above and below the relativistic electron cyclotron frequency is derived and analyzed numerically for the first time in the literature. The two principles are, respectively, cyclotron resonance maser (CRM) instability and Cherenkov instability in the azimuthal direction (CIAD). The unphysical modes at infinite values of axial wavenumber in slow wave region observed in conventional dispersion relations of the CRM instability have been remedied to stable modes near the fast cyclotron mode.

P13-05

Mapping of flux quantities in the high beta heliotron plasmas

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The mapping of the plasma parameters on the magnetic flux is very important for studies of the MHD stabilities, transport properties and so on in the high temperature plasmas of torus systems. However, the identification method of MHD equilibrium with high beta value in heliotron plasmas has not been established because the identification of the plasma boundary shape is very difficult. MHD equilibrium data needed for a transport analysis are not so many, for example, the shape of the magnetic surfaces, rotational transform, effective helical ripple and toroidal ripple of the magnetic field amplitude. The exact identification of the MHD equilibrium is not necessary to obtain the above configuration data. In LHD transport analysis, it is proposed that an equilibrium data is selected so as to fit Te profile the best in an equilibrium database with various beta values, their profiles and without toroidal current. And the configuration data except for the rotational transform are used for the transport analysis. Rotational transform is revised by the toroidal current, which is measured by MSE, or is theoretically estimated. The MHD equilibrium database is constructed by the real coordinates MHD equilibrium solver, HINT [1].

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P13-06

Development of the Web Interface for FIT Program

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In order to analyze NBI heat distribution and so on, FIT code was developed by Murakami. This FORTRAN program runs on the supercomputer to do the complicate task speedy. However, using supercomputer might become hurdle for ordinal PC users. Furthermore, this program requires the profile of electron density, electron temperature, and ion temperatures as polynomial expressions. It is difficult task for those who are not familiar with the experiments especially visitors from other institutes.
To facilitate the usage, the authors have been developing a user friendly system to run the code. The system consists of multi layers. The front end layer of the system consists of Web interface. Using normal Web browsers, users can choose the necessary parameters interactively. The next layer is server side programs mainly written by Ruby. It is a gateway from the users to the supercomputer, and it compiles the given parameter so that the FIT can use.
Using this system, the user can run the FIT code more intuitively.

P13-07a

Physics of Radiative Collapse in the Large Helical Device

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In stellarator devices the high density discharges are limited by a radiation induced temperature collapse. This density limit (Sudo limit) is usually determined at the density, when the stored energy begins to decrease as if the global power balance is lost (though the drop in the stored energy can be also attributed in part to the reduced confinement of the high density regime). There is a clear edge temperature threshold, below which the thermal instability occurs, leading eventually to the plasma collapse. The measurements of radiation profiles showed the inward propagation of the radiation zone driving the thermal collapse. This was attributed to a loss of the local power balance at the edge and thought to be triggered by the radiative thermal instability of impurities in the low temperature edge. The radiative zone develops poloidally asymmetric and roughly toroidally symmetric, as in a tokamak MARFE, irrespective to the highly 3-D magnetic field and vacuum vessel shape in LHD. This similarity helped to simulate the evolution of radiative front in a simple 1-D geometry. The calculations showed that light impurities would radiate primarily from the edge and could result in less than 100% radiated power fractions at the thermal collapse, whereas heavier impurities would radiated from the core and could result in 100% radiated power fractions at the collapse. The collapse in the former case of light impurities was partly attributed to limitations on the thermal conduction from the core to the edge resulting in the edge localized power imbalance. The role of impurity dynamic during the collapce was investigated by STRAHL code. The coupling of the thermal unstable modes with ballooning modes at the plasma edge is discussed. The scaling of edge threshold electron temperature, below which the radiative collapse can occur, is derived.

P13-07b

Impurity Transport Studies on LHD

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In this paper the impurity transport in large helical device (LHD) plasmas is studied. By means of a tracer-encapsulated solid pellet injection (TESPEL) [1] the metallic impurity have been launched into plasma and the attenuation of the emission lines from the highly ionized states has been measured and then numerically simulated by using a newly developed 1-D strllarator impurity transport code (SIT). The TESPEL method ensures a localized impurity source position and reduces an ambiguity of the total impurity amount, which makes easier the impurity particle transport studies. The SIT code can be considered as an extension of the tokamak STRAHL code [2] to nonaxisymmetric plasmas and incorporates the stellarator specific neoclassical transport coefficients and the ambipolar radial electric field solver. The SIT code has an analysis and predictive capabilities. It solves the radial continuity equations for each ionization stage of the impurity ions for given background plasma profiles and magnetic configuration. The neoclassical coefficients are based on numerical results from the DKES (Drift Kinetic Equation Solver) code and the monoenergetic Monte-Carlo calculations. The transition between the different charge states due to the ionization and recombination in balance equation is described by using the ADAS (Atomic Data and Analysis Structure) database. The impurity behavior in some typical LHD discharges with moderate and improved energy confinement and different line average density level has been considered. It is shown that the spatial distribution of impurity ions results from the competition between the radial electric field and the thermal force (which together produce a convective flux), and the diffusive term, which flattens the radial impurity distribution. The impurity ions are localized at the radial position where the convective flux goes through zero. It is also confirmed that for typical LHD discharges there are no temperature screening effect like in tokamak plasmas. Analysis of the TESPEL signal indicates that under some plasma conditions anomalous transport of impurity ions must be taken into account; however the neoclassical contribution remains essential. Finally, the effect of externally induced magnetic island on impurity screening effect and radial localization is analyzed.

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P13-07c

Stellarator Impurity STRAHL Code Development in NIFS

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The Stellarator STRAHL Impurity Transport code (SIT) has been developed in NIFS as an analysis and predictive tool for impurity ions simulation in heliotron plasmas. The SIT code is an upgrade and updated version of STRAHL code [1], which can be used for nonaxisymmertic configurations and has an extended analysis and predictive capabilities. It can be widely used for diagnostic purposes, particularly as an analysis tool in TESPEL experiments in LHD. In this paper a comprehensive description of the code is presented. The code solves the system of continuity equations (averaged over the magnetic flux surfaces) for impurity ions in each charge stage, coupled due to the ionization and recombination. It calculates the evolution of density and emission in time and space of impurity ions coming from the wall or originated within the plasma due to the pellet ablation. The new code evaluates impurity behavior in the frame of the stellarator-specific neoclassical transport, which unlike the tokamak configuration is strongly dependent on magnetic topology and the radial electric field. Under this condition the transport equations become stiff, which has required a considerable change the numerical scheme. The radial electric field is evaluated from the ambipolarity condition and depends on neoclassical transport coefficients. An analytical description of the neoclassical transport coefficient for the background plasmas (based on numerical results from the DKES code and monoenergetic Monte Carlo simulations) was generalized to impurity ions of arbitrary mass and charge state and used in the code as a neoclassical transport model for impurities. The reduction of Pfirsch-Schluter convection due to the radial electric field and its impact on impurity dynamics has been included. Calculations of the electric field and transport coefficients were included within the time dependent iterative loop. Various models of anomalous drift velocities and diffusion coefficient were also included. Currently the calculations are performed for the given plasma density and temperature profiles. In the future this calculation will be done in self consistent manner. Because of a modular structure, the SIT code will be easily incorporated into the 1-D plasma transport codes like ASTRA or PROCTOR.

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Poster Session 2(imaging)
Categories 1-4, 6, 9-12

P1-01

Somato-motor inhibitory processing in humans: a study with MEG and ERP

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The go/nogo task is a useful paradigm for recording event-related potentials (ERPs) to investigate the neural mechanisms of response inhibition. In nogo trials, a negative deflection at around 140-300 ms (N2), which has been called the ‘nogo potential’, is elicited at the frontocentral electrodes, compared with ERPs recorded in go trials. In the present study, we investigated the generators for nogo potentials by recording ERPs and magnetoencephalography (MEG) simultaneously during somatosensory Go/No-go tasks.

Eight normal right-handed subjects participated in this study. The subjects performed a warning stimulus (S1) – imperative stimulus (S2) paradigm with Go/No-go tasks. S1 was an auditory pure tone. For the S2, we stimulated the second or fifth digit of the left hand with ring electrodes. The recordings were conducted in three conditions. Condition 1 was the resting control. In condition 2, the go stimulus was delivered to the second digit of the left hand, and the nogo stimulus to the fifth digit of the left hand. The subjects had to respond to it by pushing a button with their right thumb as quickly as possible only after the presentation of a go stimulus. In condition 3, the go and nogo stimuli were reversed in the left hand. EEGs were recorded at Fz, Cz, Pz, C3, C4, F3 and F4. MEG signals were recorded with a helmet-shaped 306-channel detector array (Vectorview; ELEKTA Neuromag Oy, Helsinki, Finland). The signals were recorded with a bandpass of 0.1-100Hz and digitized at 900 Hz.

ERP data revealed that the amplitude of nogo-N140 component, which peaked at about 155 ms from frontocentral electrodes, was significantly more negative than that of go-N140. MEG data revealed that a long-latency response peaking at approximately 170 ms, termed nogo-M170 and corresponding to nogo-N140, recorded in only nogo trials. The equivalent current dipole (ECD) of nogo-M170 was estimated to lie around the posterior part of the inferior frontal sulci in the prefrontal cortex. These results revealed that both nogo-N140 and nogo-M170 evoked by somatosensory Go/No-go tasks were related to the neural activity generated from the prefrontal cortex.

Our findings combining MEG and ERPs clarified the spatial and temporal processing related to somato-motor inhibition caused in the posterior part of the inferior frontal sulci in the prefrontal cortex in humans.

P1-02

Somatosensory mismatch responses using oddball paradigm; an MEG study

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Two-point discrimination (TPD) is one of the important and frequently used clinical test to investigate the human somatosensory perception. TPD involves several factors, such as peripheral mechanoreceptors, spinal cord and the cerebral cortex relating to cognitive functions. However, its underlying mechanisms are still not clarified due to many technical problems, that is, it is very subjective test, being dependent on the examiners' skills and subjects' reactions. The objective of this study was to record somatosensory evoked magnetic fields using a somatosensory mismatch task in order to establish an objective method for TPD.

First, we determined the spatial discrimination threshold (DT) of two-point in each subject, and applied electrical stimuli to the two points of the hand with a distance of (1) DT minus (DT×10 %), (2) DT minus (DT×20 %), (3) DT plus (DT×10 %), and (4) DT plus (DT×100 %). We applied DT minus (DT×10 %) as standard stimuli, and DT minus (DT×20 %), DT plus (DT×10 %) and DT plus (DT×100 %) as deviant, respectively in different sessions.

The components peaking around 30-70 ms and 100-200ms were significantly enhanced by DT plus (DT×100 %) deviant stimuli, which were considered somatosensory mismatch components. The distance between two points became longer, the amplitude of components became larger. Therefore, we confirmed that our new method could be used for the objective examination for two-point discrimination.

P1-03

Imaging mass spectrometry revealed abnormal distribution of phospholipids in colon cancer liver metastasis

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We present the results of matrix-assisted laser desorption/ionization (MALDI) imaging and direct molecular identification using tandem mass spectrometry (MS/MS) in colon cancer liver metastasis. Cancer tissue was removed from a Japanese patient and frozen immediately without any fixations. The sections were sliced to a thickness of 3μm. The matrix for lipid ionization was 2, 6-dihydroxy acetophenone (DHA). The matrix solution was applied with an airbrush into a thin uniform matrix layer on the tissue surface. After two-dimensional laser scanning, the images were reconstructed as a function of *m/z* from a few hundred obtained spectra. In the obtained images, the existence of molecules was represented by a pseudo-color corresponding to the signal intensity. In a feasibility study, we picked up two localized signals, *m/z* 616 in a normal area and *m/z* 725 in a cancerous area. The MS/MS results suggested that *m/z* 616 was [lysophosphatidylcholine (LPC) 24:0 + Na]$^+$ or [LPC 22:1 + K]$^+$ and that *m/z* 725 was [sphingomyelin 18:3]$^+$. Thus, we successfully show the feasibility of MALDI imaging as a tool for the analysis of pathological specimens to identify molecular markers.

P2-01

CONSTRAINED ELECTRON BEAM TOMOGRAPHY FOR IDENTIFYING 3-DIMENSIONAL MOVEMENTS AND TWISTING MECHANISM OF SPERM FLAGELLA OF THE STAG BEETLE *(PROSOPOCOILUS INCLINATES)*

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The cross section of sperm flagella of a stag beetle,(*Prosopocoilus inclinates*), consists of complicated components: mitochondrial derivatives and centriole adjuncts as well as 9+9+2 microtubles (Kubo-Irie et al., 2000). We observed a clear three dimensional helical flagellar motion with an optical microscope. By negative staining method under transmission electron microscope, we also found its helical axoneme twist. In order to elucidate these mechanism, the tomography is highlighted. However the beam tilting angle in conventional electron microscope is limited to be under +/- 15° which is far smaller than those required in conventional tomography. To meet this, the soft X-ray tomography technique developed by us in nuclear fusion research (Umemoto et al., 1996) was modified into CEBT (the Constrained Electron Beam Tomography) and applied. This allows image reconstruction from smaller peripheral scanning data by setting basic assumptions as constraints. The fundamental constituents of the axoneme were detected from the local cross sectional view. The local biological deformation from this is assumed to be a superposition of the Fourier components. In this way, the three dimensional helical deformation of the flagella was described quantitatively.

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P2−02

Developments of split reporter proteins for biomolecular imaging

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A current focus of biological research is to quantify and image cellular processes in living cells and animals. To detect such cellular processes, genetically-encoded reporters have been extensively used. The most common reporters include firefly luciferase, renilla luciferase, green fluorescent protein (GFP) and its variants with various spectral properties. Herein, novel design of split luciferase reporters is described; the principle is based on complementation or reconstitution of the split fragments of reporter proteins. To demonstrate the usefulness of the split-reporter proteins, a genetically-encoded bioluminescent indicator for detecting cGMP will be presented. The basic concept is based on complementation of split fragments of Firefly luciferase (Fluc). When concentration of cGMP increases in cytosol, the amino-terminal Fluc is close enough to meet the carboxy-terminal one, and full-length Fluc is reconstituted. We showed quantitative cell-based sensing of ligand-induced elevation of cGMP. The indicator will enable noninvasive imaging of cGMP in living plants and animals. In addition, methods for detecting protein-protein interactions, which are based on split-Fluc complementation strategies, will be described

P2−03

Direct Observation of Intracellular Materials Using a Phase Contrast Transmission Electron Microscope (TEM).

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Intracellular materials can be visible with microscope once are labeled by specific markers. To observe biological specimens using the TEM, also it is requested to prepare samples with steps of fixation, dehydration, resin embedding, sectioning and staining and staining by specific markers. Their markers have many varieties include, heavy metal agents and immune or enzyme reactions. In most of these methods, chemical fixatives are necessary because of the difficulty for agents to penetrate into the cell. This procedure has, however, been introducing serious artifacts.
The phase contrast TEM has been developed to solve this problem in our laboratory (1). It has been possible to observe biological objects without staining in the ice embedded state of whole cells (2). Phase contrast TEM suited with unstained and thick samples.
We expect that the intracellular materials can directly observe intracellular materials with high resolution with phase contrast TEM without special treatment.
As the first step, we have tried to observe inorganic heavy particles in or on biological specimens, which will be extended in future for the specific protein labeling together with the immunostaining method.

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P2-04

Structural Analysis of Non-Selective Cation Channel TRPV4 using a Phase-Contrast Transmission Electron Microscope

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Transient receptor potential (TRP) family is widely expanding superfamily of non-selective cation channels; most of them are permeable for Ca2+. TRP superfamily is classified into seven subfamilies according to the sequence homology: the TRPC (Canonical) family, the TRPV (Vanilloid) family, the TRPM (Melastatin) family, the TRPP (Polycystin) family, the TRPML (Mucolipin) family, the TRPA (Ankyrin) family, and the TRPN (NOMPC) family. Some of TRPV and TRPM are known to as a temperature-sensitive channel, although each has a different range of temperature sensitivity. TRPV4 is activated by hypotonic stimuli and also by warm temperature; ~27-35oC resulting in an increase in intracellular Ca2+ concentration. All TRP channels have putative six-transmembrane (6TM) domains, which are thought to assemble as tetramer to form cation-permeable pores. To dissolve the tertiary structure of such macromolecules, transmission electron microscopy (TEM) is known as one of powerful methods. Recombinant TRPV4 was expressed using baculo virus-infected Sf-9 cells and purified using genetically attached hexa histidine-tag. The membrane fraction was solubilized by detergent and purified by affinity chromatography and following size-exclusion chromatography. The detergent solubilized TRPV4 was analyzed using a phase-contrast cryo-TEM in its size distribution and purity. The single-particle analysis of its tertiary structure has been underway and the preliminary structure has been determined.

P4-01

Imaging of tungsten impurity ejected from damaged material due to transient heat load

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Tungsten (W) has been widely used as a plasma facing component where high heat flux is concentrated because the melting temperature is highest in all the metals. However, recent experimental observations revealed that bubbles and holes were formed on the tungsten surface that was exposed to helium plasmas [1]. Furthermore, it was estimated that the formation of holes decreases the melting threshold of tungsten for the transient heat load [2,3]. In the present paper, W impurity emission from the damaged target with helium bubbles and holes due to transient heat load are investigated by 2-D imaging using ICCD (Intensified Charge Coupled Device) camera. These studies are important for investigating the effect of the pulsed heat load to materials both in inertial fusion process and in tokamaks such as disruptions and Edge Localized Modes (ELMs) on the damaged materials.

The experiments were performed in divertor simulator NAGDIS-II. The Nd:YAG laser with a Q-switch was used for the transient heat source. The emission from the neutral tungsten was detected using a ICCD combined with the narrow band optical filter of which central wavelength and full width at half maximum of the transmittance are λ=401.0 nm, and ~0.95 nm, respectively. The gate time width of the ICCD was ~100 ns. The emission from the W plume was detected as changing the time delay between the laser pulse and the trigger for the ICCD. W plume was observed in response to the laser pulses. The plume expands in time and the emission continued during several μs. The dependences of the biasing voltage of the target, surface temperature and the extent of the damage on the target will be presented in detail in the paper.

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P4-02

Near-field optical imaging of electric field and wavefunctions in metal nanoparticles

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Scanning near-field optical microscopes enable optical measurements and observations with a spatial resolution far beyond the diffraction limit of light. This allows us to investigate spectroscopic characteristics and at the same time to spatially resolve the positions point by point in nanoparticles. In this contribution, we report on near-field microscopic studies on surface plasmons in gold nanoparticles and aggregates (nanorods, triangular nanoplates, and aggregated nanospheres). We have utilized linear transmission/scattering, as well as nonlinear two-photon excitation measurements in the near-field, to observe the local electric field or electromagnetic local density of states. We show that the wavefunction of the plasmon excitation in the nanoparticle, resonant with the incident radiation field, is visualized by the near-field methods. In the aggregated nanoparticles, strong electric-field enhancement localized in the interstitial sites, which was theoretically predicted previously, is clearly imaged, and its major contribution to surface enhanced Raman scattering with the single-molecule level sensitivity is also shown by the near-field images.

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P4-03

Supported phospholipid bilayer membranes on SiO_2 and TiO_2 surfaces

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Lipid bilayer membranes deposited on solid surfaces are called "supported planar bilayers" (SPBs), and expected to be an effective cell-membrane-mimicking model system in vitro. We investigated the influence of surface properties on the SPB formation and characteristic.
We prepared SiO_2 surfaces with different surface hydroxyl groups (-OHs) density by annealing the SiO_2 layer on Si(100). Irreversible thermal desorption of -OHs reduced the surface hydrophilicity. The formation rate of dimyristoylphosphatidylcholine (DMPC)-SPB from 100-nm-filtered vesicles was faster on less hydrophilic surfaces. We proposed that a stable hydrogen-bonded water layer on the SiO_2 surface worked as a barrier to prevent vesicle adhesion on the surface. The water layer stability and its dependence are discussed from theoretical calculation results using Si-O cluster models. The surface -OH density little affected the fluidity of once formed SPBs, which was measured by the FRAP method. Application to the area-selective SPB deposition using surface patterning by the focused ion beam will also be described.
We also investigated the effects of surface atomic structures and photo-induced hydrophilicity on single-stepped rutile-TiO_2 low index surfaces. Single-stepped TiO_2(100) surface was prepared by HF aq. treatment and annealing at 700°C at O_2 flow. The DMPC 50-nm-filtered vesicles transformed to planar bilayer on the O_2-annealed TiO_2(100), but adsorbed as vesicles on the UV-irradiated TiO_2(100). Trace of single steps was recognized on the SPB on the TiO_2(100).

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P6-01

Charge transfer in collisions of proton with CH3 molecules

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Various types of molecular impurities such as hydrocarbons have been detected near edge plasma region like divertor. These impurity gases are considered to play a crucial role for determination of plasma temperature and density. In addition, these impurities gases may be utilized as a mean of plasma diagnostics. Among these hydrocarbons, CH, CH2 and CH3 radicals are known to present and emitted photon from these molecules are now widely used as a plasma spectroscopy for diagnostics. Therefore, we undertook the project to investigate charge transfer in collision of protons and He2+ ions with CH3 molecules in the collision energy from a few tens of eV up to 10 keV. Most of molecular ions produced through ionization are known to be unstable and undergo fragmentation. Hence, identification of fragmented species and their production mechanism are important for spectroscopic analysis. The adiabatic potential- energy curves and corresponding wave functions are caluculated by Buenker group using the multireference single- and double-excitation configuration interaction (MRD-CI) method, with configuration selection and evergy extrapolation. And the scattering dynamics is studied on semiclassical impact parameter molecular-orbital close-coupling (MOCC) method.

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P6-02

Fulcher-α spectra in the mixed hydrogen isotope plasma

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In the edge region of fusion relevant devices, the behavior of hydrogen molecules is related to the global particle balance including external fueling/pumping and wall recycling. Moreover, the hydrogen atoms produced by the dissociation of vibrationally excited molecules play significant role in the determination of the neutral penetration depth across the separatrix. It is capable of giving helpful clues to the understanding of detailed molecular and atomic processes related to such phenomena by diagnosing the rovibrational temperature of the electronic ground state of hydrogen molecules. In the analysis of rovibrational population, the Fulcher-α band Q-branch spectra ($d^3\Pi^-_u \rightarrow a^3\Sigma^+_g$) have been used since the transition wavelength is in visible region and there are relatively few perturbations. The development of the techniques for analyzing the Fulcher-α band has been undertaken mainly in the plasmas containing single molecular species such as H_2 or D_2 so far. From the practical point of view, however, it is necessary to investigate the mixed hydrogen isotopes [1,2], in particular, on the overlap of transition lines and on the possible difference in the rovibrational temperatures.

In the present study, we have measured the Fulcher-α band spectra in the mixture plasma of hydrogen isotope molecules. Experiments were performed using a dc-arc discharge in a divertor plasma simulator MAP-II [3]. In order to analyze the observed Fulcher-α band spectra, the coronal model was combined with the calculation of the spectral line shape based on the diagonalization of the Hamiltonian matrix elements for diatomic molecules [4].

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P6-03

Analyses of visible images of the plasma periphery observed with tangentially viewing CCD cameras in the Large Helical Device

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Large Helical Device (LHD) is the largest super-conducting helical machine. The super-conducting coils consist of three pairs of poloidal coils and two twisted helical coils which have three independent conductive layers for changing the coil pitch parameter (γ). The magnetic field produced by the poloidal coils can control the plasma shape by changing quadruple magnetic components (B_Q). Magnetic field configuration produced by the two super-conducting coils form a complicated structure of the magnetic field lines (ergodic layer and divetor legs) around magnetic surfaces (plasma confinement region). The control of electric currents of these coils provides flexible change of magnetic configurations for plasma confinement. It can change the radial position of the magnetic axis (R_{ax}), the shape/size of magnetic surfaces, the thickness of the ergodic layer, and the location of the strike points, etc.

Tangentially viewing CCD cameras have routinely monitored the images of visible light in the plasma periphery and the divertor legs in various magnetic configurations. Complicated structure of the visible light depending on the magnetic configurations has been observed, which provides some significant experimental and physical information about the location of the strike points, the structure of the ergodic layer and the divertor legs, atomic and molecular processes in the plasma periphery, and plasma wall interactions on divertor plates, etc.

Three-dimensional magnetic field line trace in the plasma periphery is a powerful technique for analyzing and interpreting the observed images of the visible light. The images of the calculated magnetic field lines from the position of the CCD cameras quite agree with the observations in various magnetic configurations, which can show the correspondence between the complicated structure of the visible light and the three-dimensional structure of the peripheral plasma forming along the magnetic field lines.

In this paper, the observed images of the visible light emitted from the peripheral plasma and divertor legs are investigated from the viewpoint of the three-dimensional structure of magnetic field lines in the plasma periphery. The calculated distributions of the strike points in various magnetic configurations will be shown for determining the operational range of the magnetic configurations (various R_{ax}, γ and B_Q) which can satisfy the experimental condition that most of the strike points locate on the divertor plates for safe operation in LHD.

P6-04

A new Doppler shift spectroscopy for the measurement of neutral beam profile

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A new diagnostic base on Doppler shift is designed which measures the profile of hydrogen or deuterium neutral beam on the magnetic confined fusion machines. The interference filters and multi-channel PIN detectors are the main components of this diagnostic. The multi-channel PIN detectors measure the line integer Doppler Ha signal emitted by the neutral beam at one section in two directions. The local intensity of neutral beam can be obtained with the tomography technololy. Compare to the conventional calorimeter diagnostics, this diagnostic can provide the beam profile without blocking the injection of neutral beam.

P6−05

Observation of Hydrogen and Cesium Spectra in a Negative Ion Source for a Neutral Beam Injector using a Multi-channel Spectrometer

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Production of a negative hydrogen ion is one of the key issues for a high-energy neutral beam injector (NBI). Two large size negative-ion sources are installed in each negative-ion based NBI system to heat plasma in the Large Helical Device (LHD). Cesium vapor is seeded to enhance the production of negative hydrogen ions into our ion sources, but the behavior of cesium ions and the neutral particles has not been observed continuously at NBI operation.
We adopted the multi-channel visible spectrometers in order to observe the behavior of hydrogen spectra and cesium spectra. Plasma emissions, which are path-through a quartz window, are focused on the two quartz optical fibers in an optical connector by lens. One optical fiber is connected to a wide range survey spectrometer (PLASUS EmiCon 4ch), and the other optical fiber is connected a high-resolution spectrometer (ANDOR shamrock) with a multi-channel configuration. In order to obtain spatially resolved data, we used five observation view ports and five bundled optical fibers to observed the behavior of the hydrogen arc discharge and the cesium dynamics. We have calibrated these spectrometers by using an Ulbricht sphere (SphereOptics LR-12-M).
We have clearly observed the Balmer emission spectra, molecule hydrogen Fulcher lines, oxygen neutral spectra, cesium neutral spectra, and cesium ion spectra. Intensity of hydrogenous spectra increases as a function of input arc power at each observing position. Cesium signal increases by increasing the total evaporation time, and the signal jumps up for beam extracting duration. We have also observed a difference of the intensity of the cesium neutral spectrum between the observation from the back plate and from the upper side view port, which indicates on higher degree of ionization of cesium in the bulk plasma.

P6-06

A Multi-reflection Type Visible-laser Interferometer for High Density Plasma Measurements

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A magneto-plasma-dynamic arcjet (MPDA) is utilized as a high-enthalpy plasma source not only for a plasma injection source for open magnetic confinement experiments but for an electric propulsion and several industrial applications. Detailed measurement of plasma density in the vicinity of an MPDA is important to evaluate its performance. The interferometry method [1] using electromagnetic waves is useful and convenient to obtain a line-integrated plasma density. As a plasma density in the vicinity of an MPDA is more than 10^{14}cm^{-3}, it is difficult to measure a plasma density by an electrostatic probe. The purpose of this research is to develop a laser interferometer for measurement of a high density plasma in the vicinity of an MPDA .
The feature of this interferometer is to use a He-Ne laser (λ= 632.8 nm) and a multi-reflection optical system. A He-Ne laser is easily obtained and easy to handle as visible light. Although it doesn't have enough phase shift when the light passes through the MPDA plasma once, we adopt a multi-reflection optical system in this interferometer to improve the phase sensitivity. A phase is detected using the Michelson-type interferometer, where a He-Ne laser (10mW) was used as a light source. The probe beam passes through the MPDA plasma[2] and reflected between a corner cube mirror and a flat mirror many times. The phase shift of 21 degrees is expected when the light passes 10 times through the plasma with line-integrated density of 3×10^{15}cm^{-2}. The interferometer was attached to the HITOP device[3] and an MPDA is operated with 1ms duration quasi-steadily. We measured a plasma density by the interferometer and estimated the maximum value of line-integrated density of 3×10^{15}cm^{-2}. These experimental results are consistent with that of the electrostatic probe measurement in the downstream region.

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P6-07

Development of real-time measurement system of charge exchange recombination spectroscopy and its application to feedback control of ion temperature gradient in JT-60U

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In magnetically confined plasmas, the control of the pressure profile is important subject for sustaining high performance plasmas and/or avoiding MHD instabilities. Real-time measurement system of ion temperature has been developed for the feedback (FB) control of the ion temperature profile including temperature gradient with the filter charge exchange recombination spectroscopy (CXRS) system in JT-60U [1,2]. In the filter CXRS system, the ion temperature can be evaluated by the simplified fitting functions using the intensity ratios of three sets of interference filter assemblies assuming a Maxwellian shape of the spectral profile of the CXR emission. This rapid analytical scheme without non-linear least square fitting enables us to calculate the ion temperature with four spatial points every 10 ms using a real-time processor (RTP) system [3]. The real-time control experiment of the ion temperature has been demonstrated in the ELMy H-mode plasmas. The central ion temperature has been controlled in the range from 2 to 7 keV using 9 units of neutral beam injector (maximum 18 MW) as actuator. By optimizing the proportional and differential gains in FB systems, the central ion temperature almost agreed with the reference one. The measurement system has been modified to obtain the suitable signal-to-noise ratio and space- and time- resolutions for the real-time FB control of the ion temperature gradient. The experiment of the FB control of the temperature gradient is started aiming at sustaining the high normalized beta plasma with suppressing MHD instabilities such as neoclassical tearing modes.

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P6-08

Temperature Diagnostics for Field-Reversed Configuration Plasmas on the Pulsed High Density (PHD) Experiment

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The High Flux Source (HFS) for the Pulsed High Density Experiment (PHDX) has been constructed, and experimental studies to produce field-reversed configuration (FRC) plasmas are under way. The PHDX will expand the conventional regime of the FRC to the very compact, high energy density regime to approach fusion. In this approach, the energy needed to compress the FRC to fusion conditions is transferred to the FRC via simple, relatively low field acceleration/compression coils. The experiment is essentially the first step, and continuing progress towards breakeven can be made in incremental steps with additional stages of acceleration and compression. Initial studies explore pre-ionization and formation methods used to create high flux FRCs on the PHDX.

To obtain the electron density and temperature of the FRC plasma a λ=632.8 nm He-Ne laser interferometer system is set up near the midplane of the HFS, and to estimate the ion density and temperature a 16 channel spectrometer has been installed for end-on viewing. Other diagnostic systems include an axial array of magnetic probes and flux loops, 64 channel array of optical measurement system for visible bremsstrahlung tomography, 14 channel array of line-integrated visible light measurement, a gated single spectrometer, a bolometer, and an end-on framing camera. For more detailed density and temperature analyses a soft x-ray measurement system is being developed on the end flange of the HFS; this system consists of 5 AXUV100 photodiodes with directly deposited filters which have approximately 0.1−0.3 μm thick films (Al, Zr/C, Sn/Ge, Cr/Al, and Ti/Pd) on each diode. Both parameters of electron temperature T_e and electron density n_e are approximately determined by comparing the response of the several filtered detectors to their computed response using the emissivity from an atomic model of the plasma with T_e convolved with the spectral responsivity of each detector. To estimate the sample spectrum on the PHDX, the spectral analysis code (from the Prism Computational Science, Inc.) is used. Once we have an emissivity for some nominal choice of impurities, we can use simple scaling with impurity density to assemble an emissivity spectrum for a combination of impurities. We will present both computational and experimental results from the soft x-ray measurement system and the comparison of all density and temperature diagnostics for FRC plasmas on the PHDX.

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P6-09

A simultaneous spectroscopic measurement for the global and edge fine structures of the ion temperature and plasma rotation profiles in the Compact Helical System

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In charge exchange spectroscopic (CXS) measurements[1] to investigate radial distributions of ion temperatures $T_i(r)$, poloidal rotation velocities $V_p(r)$, and impurity densities $n_I(r)$ in magnetically confined toroidal plasmas, a simultaneous observation in different plasma toroidal cross sections and/or viewing ports is required. One reason is a need to monitor the background radiation obscuring the spatial resolution. Another requirement is to detect the Doppler shifts correctly with visible spectrometers in which mechanical wavelength offsets of ~0.5Å cannot be eliminated. The best approach to detect the correct Doppler shifts is simultaneous viewing from opposite directions. In addition to these problems, the toroidal asymmetry of the plasma geometrical shapes brought another requirement especially in recent studies of edge transport barriers (ETB) in helical plasmas. From several edge plasma measurements in the Compact Helical System (CHS), it has been suggested that the edge pedestal region, where the ion pressure gradients and corresponding ion rotation are expected, is very narrow (for e.g., $\Delta r/a<0.1$, where r and a are minor radii of measured flux surfaces and the outermost flux surface) if it exists. Detections of the rotations and the ion temperature profile in the narrow region are impossible with previous CXS system at a vertically elongated section in CHS with the chord spacing ΔR=7.5mm corresponding to a spatial resolution of $\Delta r/a$=0.06. To improve this spatial resolution, we carried out a CXS measurement at a horizontally elongated cross section. The chord spacing ΔR=6.3mm at the equatorial plane Z=0 corresponds to a spatial resolution of $\Delta r/a$=0.02. We measured radial profiles simultaneously at both of the vertically elongated sections to obtain global structure in $0<r/a<1$ with 24 chords × 2 directions, and the horizontally elongated section for the local fine structures at the edge pedestal region at $r/a\approx1$ with 9 chords. The total 90 fibers including chords for the background radiation are connected to one spectrometer. A 256×243pixels sampling CCD with an image intensifier is used to detect the diffraction image. As a result of the analysis including the corrections and calibrations for various apparent wavelength shifts such as those by the spectral fine structure[1] and the aberration, it is found that there is a localized edge ion temperature pedestal structure of $\Delta T_i\approx$100eV and $\Delta r/a\approx0.1$, and the negative radial electric field of -10kV/m is increased there in the high confinement phase.

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P6-10

Simultaneous Measurement of Proton Ratio and Beam Divergence of Positive-ion-based Neutral Beam in the Large Helical Device

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Positive-ion-based neutral beam injector (P-NBI) was installed in the Large Helical Device (LHD) at 9th experimental campaign (2005-2006). The neutral hydrogen beam with energy of 40keV was injected into LHD plasmas, and was utilized as a diagnostic neutral beam (DNB) for a charge-exchange spectroscopy measurement. The low energy beam has a higher efficiency of ion heating than that of high energy beam (180keV) produced by negative-ion-based neutral beam injectors (N-NBIs) installed in LHD, so ion heating experiments were also performed using the P-NBI. In order to evaluate heating efficiency, it is necessary to know proton ratio of the beam because half and one-third energy components are included in the beam produced by P-NBI, and they affect beam deposition and heating efficiency. On the other hand, monitoring of the beam divergence is important for stable beam operation and accurate estimation of port-through power of the beam. Thus, we developed a simultaneous measuring system of the proton ratio and the beam divergence.

In order to measure both proton ratio and beam divergence, the beam emission spectroscopy in the P-NBI was designed and performed in 9th LHD campaign. The line of sight crosses the beam diagonally to obtain both parallel and perpendicular components to the beam direction. The H_{α} emission from neutral hydrogen beam shows three lines near the H-alpha emission from background hydrogen gas due to Doppler-shift of the beam, and they correspond to full, half, and one third energy components. The intensity of each line is sensitive to the arc power (perveance), and the proton ratio decreases and one-third component increases in low arc (perveance) operation. The Doppler broadenings of each line reflect the beam divergence. The beam let focus effects and other geometrical effects are also included the broadening of these lines, but they are almost constant in the beam operation. The width of full energy spectrum in wave length space was compared with beam width measured on the calorimeter, and the linear relation between them was clearly seen. These results show that this system is useful for monitor of proton ratio and beam divergence. We also discuss the reliable estimation of port-through power of the beam using combination of optical measurement of beam divergence and calorimetrical measurement on an armor tile.

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P6-11

Infrared Imaging Video Bolometer with a Double Layer Absorbing Foil

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The idea of infrared imaging bolometry is to absorb the incident plasma radiation in an ultra thin (1μm- 2.5μm) metal foil, to measure the temperature rise of the foil remotely by means of infrared video camera and finally to calculate the incident radiation power flux as a function of measured temperature rise. Initially [1] metal foil pixels were thermally isolated by two segmented supporting plates. The central part of the plates was later eliminated [2] and a large (10 cm × 10 cm) foil was supported by a copper frame. The thermal fluxes between the neighboring pixels were calculated and taken into account during a special reconstruction procedure.
To achieve the most effective transformation of the incident radiation power flux into infrared radiation measured by an infrared camera one should provide good thermal isolation of each bolometer pixel from the other pixels and from the supporting frame. The object of the present paper is an infrared video bolometer with a bolometer foil consisting of two layers: the first layer is constructed of radiation absorbing blocks and the second layer is a thermal isolating base. The absorbing blocks made of a material with a high photon attenuation coefficient (gold) were spatially separated from each other while the base should be made of a material having high tensile strength and low thermal conductance (stainless steel). Such a foil is being manufactured in St.Petersburg and will be calibrated in NIFS using a vacuum test chamber and a laser beam as an incident power source. A finite element method (FEM) code was applied to simulate the thermal response of the foil. The FEM predicts a higher temperature by a factor of two with the double layer foil than the single foil IRVB using the same absorber material and thickness and shows negligible crosstalk between the pixels. The calibration data will be compared to the results of the computer simulation.

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P6-12

Two-dimensional measurement of inward neutral flux in LHD

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Three emission lines of neutral helium, i.e., the λ 667.8 nm (2^1P - 3^1D), λ 728.1 nm (2^1P - 3^1S), and λ 706.5 nm (2^3P - 3^3S) lines, are observed with a set of parallel lines of sight which covers an entire poloidal cross section of the plasma in the Large Helical Device (LHD). Their emission locations and intensities are individually determined with the help of observed Zeeman profiles, and the electron temperature and density are evaluated at each emission location by means of the intensity ratios among the observed three emission lines. From these results and collisional-radiative model calculations, the poloidal distribution of ionization flux or its equivalent quantity, inward neutral flux, is determined with high accuracy. The result shows strong inhomogeneity in the two dimensional neutral flux distribution: the flux is relatively strong in the vicinity of the inboard side X-point. This implies high particle recycling in the inboard side divertor region which has been also suggested by the Langmuir probe measurement of the ion flux onto the divertor plates and the neutral transport simulation.

P6-13

Design of Impurity Influx Monitor (Divertor) for ITER

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The main function of the Impurity Influx Monitor (Divertor) for ITER is to measure the parameters of impurities and isotopes of hydrogen in the divertor plasmas by using spectroscopic techniques with the wavelength range of 200 - 1000 nm. The measurements are required for the full duration of the ITER pulse and special provisions are necessary to provide the measurements in the harsh environment such as high radiation field and/or high temperature for diagnostic components. In order to perform the two-dimensional measurement in the poloidal plane, this monitor observes divertor region using four optical systems; from the divertor cassette, through the gap between the divertor cassettes, from the equatorial and the upper port.

In the optical design of each optical system, simple Cassegrain telescope is used as a collection optics. In addition the micro lens array will be inserted just in front of fiber bundle to extend the observed area to toroidal direction. The effective size of a vacuum window is 120 mm φ in this design. The spatial resolution estimated from the irradiance distribution will meet the ITER requirement for the spatial resolution of 50 mm.

The mechanical design of mirror folders for the front-end optics of the upper, the equatorial, and the divertor port is performed. In the upper port, the front-end optics consists of three mirrors. They are mounting on the mirror mounting module of 300 mm diameter which will be installed inside the pipe with inner diameter of 300 mm replaced with that for the remote-handling of the port plug. It has many cooling channel to remove the nuclear heating. The effect of the thermal strain to the optical property is estimated by the simple steady state heat analysis and the optical design code assuming the constant nuclear heating of 0.2 MW/m^3. The result indicates that the temperature rise of the mirror and mirror mounting module is < 60°C and the difference of the thermal strain on the mirror surface is less than 0.08 mm. Optical design code suggests that this difference causes only small movement of the optical path.

P6-14

2-d image diagnostic technique for edge turbulence using fast cameras

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Two-dimensional imaging technology is widely used in plasma physics recently. In pariticular, high-speed camera has been using for this above aim since twenty years ago. Progress of these cameras are very splendid and typical shutter speed of the latest models are faster than 100,000 frames per second. Using a fast camera the edge turbulence measurement was demonstrated mainly in GAMMA 10 and Heliotron J by Bi-directional collaborative activities. In this paper, the results obtained in both device are presented.

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P6-15

Two-dimensional measurement of plasma dynamics with an ICCD fast camera based on HeI line intensity ratio method

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The investigation of dynamic behavior of edge plasmas in fusion devices has received considerable attention associated with edge localized mode (ELM) and disruption. In the International Thermonuclear Experimental Reactor (ITER), it is considered that the intermittent plasma heat load due to the ELMs and disruption determine the lifetime of the plasma-facing components. In order to understand the dynamics of ELMs and disruption in the edge plasma regions, the spatial- and time-resolved measurement of electron temperature and density is necessary.
Improvement of collisional radiative (CR) model of He can make it possible to measure electron density as well as temperature with better accuracy by using HeI lines (667.8 nm, 706.5 nm and 728.1 nm) [1]. Recently, dynamic behaviors of ELMs and disruption were measured by the spectroscope equipped with three optical filters and photomultiplier tubes, which can detect the HeI lines, simultaneously.
In order to measure two-dimensional plasma dynamics in ELMs and disruption, we are developing an ICCD fast camera with the HeI optical filters, which can give 3 images for the HeI lines, simultaneously. In this presentation, we will report the detail of the ICCD fast camera, including the calibration method. We will also present the preliminary experimental results of the dynamic 2D measurement in the small tokamak.

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P6-16

High-speed visible imaging of central-cell plasmas in the GAMMA 10 tandem mirror

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Behavior of edge plasmas and neutral particles plays an important role on plasma transport and recycling phenomena in magnetically confined plasmas. The gas puff imaging (GPI) diagnostic with high-speed camera provides useful information on the behavior of edge plasmas as two-dimensional (2-d) images of visible light emission [1,2]. Recently, in the GAMMA 10 tandem mirror, observation of the plasma motion using high-speed camera was started in the central-cell [3]. Neutral hydrogen density in the central-cell also has been evaluated by measuring H_α line-emission together with neutral transport simulation using the DEGAS Monte-Carlo code [4] in order to investigate the neutral particle behavior in the tandem mirror plasmas [5-6]. GAMMA 10 consists of an axisymmetric central-mirror cell, anchor-cells with quadrupole magnetic configuration, and plug/barrier regions with axisymmetric mirrors in which plasma confining and thermal barrier potentials are produced. In GAMMA 10, 2-d visible measurement by using two high-speed cameras (Ultima-SE, Photron Inc. and K4, NAC Inc.) was performed recently based on bi-directional collaboration between Hiroshima and Tsukuba Universities. In standard hot-ion-mode plasmas, hydrogen puffing with a short pulse (3 ms) near the central-cell midplane was carried out and the time evolution of visible light emission from the gas cloud was precisely investigated. In the latest collaboration experiment, 2-d images of the ablation light induced by hydrogen ice-pellet injection are also successfully captured for the first time at the GAMMA 10 central-cell. In this paper, the results of 2-d imaging obtained with the high-speed cameras are precisely presented and the detailed behavior of periphery plasmas and neutrals is analyzed in terms of edge plasma turbulence and neutral transport simulation analyses.

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P6-17

Behavior of Hydrogen Fueled by Pellet Injection in the GAMMA 10 Tandem Mirror

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Sustainment of the steady state plasmas with higher densities and temperatures is one of the most important subjects to realize the fusion reactor. The development and optimization of the fueling method enable us to increase and sustain plasma density. In the present plasma experiments, there are three major fueling methods; namely, gas puff, neutral beam injection and pellet injection. Pellet injection is used as a particle source in the core region of the plasma. The importance of pellet injection is highlighted under the condition at high density and high temperature plasmas. To study the effects of the pellet injection on the target plasma, it is important to evaluate the neutral hydrogen behavior as well as plasma densities and temperatures.

In the GAMMA 10 tandem mirror, the study of particle fueling has been carried out for the purpose of producing high performance plasma discharges [1, 2]. In the central cell of GAMMA 10, the pellet injection system is installed near the mid-plane to improve plasma parameters and to study the pellet-plasma interactions in an open system [3, 4]. H_α and H_β line emission detector arrays [5] are used to estimate the behavior of fueled particles.

In recent experiments, hydrogen pellets are injected with electron cyclotron resonance heating at the plug/barrier and central cells. Consequently, increases in electron densities and Hα line emission with several peaks are observed. The spatial profile of H_α line emission has a peak in the peripheral region of the injection side. These results show that the pellet cracks into some small pieces somewhere of the injection path. In this paper, we discuss the behavior of pellet and plasma parameters, in particular the radial and axial profiles of H_α line emission, caused by the pellet injection.

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P6-18

Measurements of Oxygen Ion Spectra for Estimation of Electric Field Profiles in Cylindrical Plasmas

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In fusion plasmas, electric field profiles play an important role in improvement of plasma confinement. In torus plasmas, such as tokamak and helical systems, an H-mode and an internal transport barrier are associated with the electric field profiles. In tandem mirror systems, the electric field profiles play similar role [1, 2]. Mirror devices, having open-ended regions, provide intrinsic important advantages in terms of the control of radial-potential or sheared E&timesB rotation profiles on the basis of axial particle-loss control. In order to study physical basis of the improvement of plasma confinement, measurements of the electric field profiles in various plasmas are of essential importance. We have developed a measurement technique of the electric field profiles by using a ultra-violet/visible (UV/V) spectroscopy and a collisional-radiative model (CR-model) in cylindrical plasmas [3]. The CR-model was used for estimation of a diamagnetic drift via evaluation of a impurity density profile. In that study, the CII spectrum (426.726 nm: $2s^2 3d(^2D) – 2s^2 4f(^2F)$) was observed, since the CR-model calculation code for carbon ions has been developed already [4]. However, the CII emission had very low intensity even if the spectroscopic system had the maximum sensitivity in a wavelength region around 430 nm in the GAMMA 10 tandem mirror. The spectra from oxygen ions (OII, OIII OIV and OV) have high intensity in UV/V region in the GAMMA 10 central cell and anchor cells. While there was no CR-model calculation code for lower charge states of oxygen ions. Recently, we started to construct the CR-model for oxygen ions for GAMMA 10 plasma measurements. We evaluated the density profile of oxygen ions by using our new code [5, 6]. Moreover, CCD camera system was revised to achieve the higher wavelength resolution than that of the previous system. In this paper, we show observed results of electric field profiles by using the new spectroscopic system and the newly constructed CR-model for oxygen ions.

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P6-19

Study of Edge Plasma Characteristics at H-mode Transition in Heliotron J

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Spontaneous transition to a high confinement mode (H-mode) was observed in a helical-axis heliotron device, Heliotron J [1]. Typical transition phenomena were characterized by a drop in H_α signal and an increase in stored energy and electron density. The transition frequently occurs in low (B_{04}/B_{00} = 0.01) and medium (B_{04}/B_{00} = 0.06) bumpiness configurations compared to high one (B_{04}/B_{00} = 0.15) under the condition of the same electron density and the ECH. These results suggest that the field configuration has an important role on triggering the transition.

We have measured radiation profiles using multi-channel photodiode and AXUV detectors which cover a wide wave-length range from visible to soft X-ray. The plasma radiation drops in the scrape off layer (SOL) just after the H-mode transition for all three configurations, suggesting the formation of the edge transport barrier. We have also observed a characteristic time-evolution of the radiation profile near the transition phase, which depends on the configuration. In low- and medium-bumpiness configurations, an in-out asymmetric change of radiation profile is observed before the transition, and the radiation increases inside the last closed flux surface after the transition. On the other hand, the radiation increases with keeping the profile shape a parabolic one except the SOL before and after the transition at high bumpiness configuration. These differences of the edge asymmetric changes may be related to the formation of the edge transport barrier.

In order to investigate the edge structure, the characteristics of edge plasma fluctuation before and after the H-mode transition are investigated by analyzing the probability density functions (PDFs) of the ion-saturation current fluctuation measured with a Langmuir probe set [2]. In the L-mode phase, the skewness and the kurtosis are larger than the Gaussian PDF for all three configurations. As approaching the transition timing, they start to decrease, and the PDF becomes nearly Gaussian one. It is this phase when the asymmetric evolution of the edge radiation is observed in the medium bumpiness configuration and the stored energy and the electron density increased modestly. The characteristics of L- and H-modes will be discussed with regards to the non-Gaussian plasma edge turbulence.

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P6−20

Spectroscopic measurements of emission spectra by using multi-channel UV/visible impurity monitor

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Measurements of impurity emission spectra from fusion plasmas are very important to investigate impurity behavior, wall condition and radiation loss. In GAMMA 10, the spectroscopic measurements have been performed at wavelength range of ultraviolet and visible (UV/visible), vacuum ultraviolet and soft X-ray[1-5]. We constructed new UV/visible spectroscopic system for impurity monitor using two multi-channel spectrometers. One of the spectrometers can measure the absolute intensity of the spectra in the wavelength range of 200-500 nm; the other, 400-700 nm. This system provides the advantage of measuring the entire wavelength range of the UV/visible radiation spectra in a single plasma shot. The spectroscopic measurements of impurity spectra by the impurity monitor system have been carried out in GAMMA 10 central cell. The time-varying emission intensities of radiation spectra were successfully measured in a single plasma shot. The line identification was performed for measured data. Then, the shot trends of several line spectral intensities were obtained. Using these spectral intensity data measured in this experimental series, the plasma parameter dependence of radiation loss and emission intensities in the UV/visible range are evaluated. Moreover, we estimated the electron density and temperature after applying the measured hydrogen spectral intensity data to a collisional-radiative model in each plasma shot.

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P6-21

Line analysis of EUV spectra from molybdenum and tungsten injected in LHD

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Spectroscopic data on high-Z materials for impurity diagnostics are important due to its possible use as a plasma facing component in the next generation fusion device. For this purpose molybdenum and tungsten are injected by an impurity pellet injector into the LHD plasmas. Emissions from such highly ionized elements mostly fall in the Extreme Ultra Violet (EUV) and soft X-ray ranges. The EUV spectra in a range of 50-500Å are recorded using a flat-field EUV spectrometer. The observed emissions are identified with the help of its temporal evolution and detailed analysis is done with electron temperature profiles. At high central electron temperature (~2keV) molybdenum appears as an Al-, Mg- and Na-like ionization stages. Typical examples of identified transitions are MoXXXI 190.46Å ($3s^2\ ^1S$ – $3s3p\ ^3P$) and MoXXXII 176.63Å ($3s\ ^2S$ – $3p\ ^2P$). For tungsten, on the other hand, individual lines appear along with a strong quasi continuum structure around 50-70Å. These transitions have been identified and compared with previous studies and also with calculated values.

P6-22

Fast XUV 16×16 array hybrid module for plasma imaging applications

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AXUV detectors manufactured by IRD Inc. (USA) are quite popular in plasma research owing to high sensitivity, fast response and almost flat spectral curve in 30…5000 eV photon energy range [1]. Unfortunately, the company does not produce matrix arrays required for imaging applications. The main goal of the present work is the development of a multiple-scaling matrix approach with the use of similar XUV Si photodiodes (SPD diodes).

Basic 16×16 hybrid module is comprised of eight stacked sub-modules of 2×16 linear SPD diode arrays combined with a circuit board with a 32-channel preamplifier and four 8-channel fast multiplexers. The array front size is 31×31 mm with a filling factor of 25% (single element size is 1.22×0.88 mm). The module length is 65 mm.

The module has a “zero-edge” design providing an option of stacking into the larger arrays, if necessary. For preliminary testing it is packed into a pinhole camera of 38×38×155 mm size with variable field-of-view and 50-pin output connector.

The data acquisition system (DAS) is comprised of eight 4-channel synchronous 12-bit ADC modules with 40 MS/s upper sampling rate, thus providing less than 1 μs total frame time of the array module. Each channel has a 64 MB on-board memory limiting the duration of the acquired period to 0.8 s at the maximum sampling rate. Common Ethernet 10/100 Base TCP/IP protocol is used for data transmission into the main PC operating as a DAS control console, data preview and storage computer.

Preliminary testing results and application to plasma diagnostics are discussed.

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P6-23

Comparison of Three Types of Impurity Diagnostics on Reheat Mode Discharges in the Compact Helical System

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Three different types of impurity diagnostics have been equipped in the Compact Helical System (CHS), a medium-size helical device. A single channel pyroelectric detector is used for routine monitoring of total radiation power from the plasma as a conventional bolometer. In addition, we have employed unfiltered absolute extreme ultraviolet (AXUV) photodiode arrays as a simple and low-cost diagnostic to measure spatial and temporal variations of radiation emissivity within a horizontally elongated cross section [1]. On the other hand, we have utilized a flat field grazing incidence spectrometer for the survey of vacuum ultraviolet (VUV) spectra in the wavelength range of 10-110 nm at a spectral resolution of 0.3 nm [2]. The viewline of the spectrometer is fixed at a line passing through the plasma center.
An improvement of the stored energy has been observed temporally after the termination of the intense gas puffing in high density CHS plasmas, which is called reheat mode [3,4]. Characteristic features of the impurity diagnostic signals are observed in the reheat mode discharges. After entering the reheat mode, total radiation power measured by the pyroelectric detector significantly reduces, whereas the AXUV photodiode signals increase especially for the center viewing chord. One possible reason for this opposite behavior is the reduction of the sensitivity of the AXUV photodiode in the VUV region, especially for longer wavelength side. In order to assess this assumption, temporal evolutions of the VUV spectra were measured in a reheat mode discharge at 10 ms intervals. As a result, the emissions from highly charged metallic ions in the shorter wavelength region largely increase in the reheat mode, while the emissions from relatively low charged oxygen ions in the longer wavelength region decrease conversely. These observations implies that the metallic impurities accumulate in the plasma core, and that the opposite behavior between the two bolometric detectors could be attributed to the difference in the spectral sensitivity in the VUV region.

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P6-24

Improvement of AXUV bolometric measurement system at a semi-tangential cross-section in LHD

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The space- and time-resolved study of the dynamic behavior of plasma radiation in magnetically confined plasmas is still important to acquire a better understanding heat and particle transport in those plasmas. In the Large Helical Device (LHD), two Absolute eXtreme UltraViolet photoDiode (AXUVD) arrays (20 channels + 20 channels) have been installed at a semi-tangential cross-section in LHD [1] to obtain a two-dimensional image of the plasma radiation with the aid of some tomographic algorithms, such as Tikhonov-Phillips regularization. The reconstruction of the 2D tomographic image from the data of two-AXUVD arrays successfully shows a highly localized radiation pattern in the semi-tangential cross-section when a strong gas puffing or a pellet injection has been implemented [2]. In order to improve the accuracy of the reconstructed 2D tomographic image, the applying algorithms are being improved continuously, which brings better results [3]. To ensure the improvement of the 2D tomographic image, from the 10th experimental campaign of LHD, the new AXUVD array will be available at the same semi-tangential cross-section. The signal conditioning system and the data acquisition system for this AXUVD array are also upgraded. In the conference, the detail of the newly installed AXUVD array at the semi-tangential cross-section and the initial data obtained by the three-AXUVD arrays will be presented.

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P6-25

Spectroscopic Study of Plasma Flow Generated by Magnetoplasma Compessor with Transparent Electrodes

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A magnetoplasma compressor (MPC) with a semi-transparent electrode system operating in the ion current transfer regime has been constructed and studied. The electric and thermodynamic parameters of the discharge and plasma flow created in different gases have been measured in order to optimize the working conditions within a large pressure range (from 200 to 3000 Pa) and the energy input up to 20 kJ. A special construction of an accelerator electrode system shielded by the self-magnetic field results in protection from erosion which is the main cause of the high current cut-off in conventional plasma accelerators [1]. The electron temperatures and densities were measured by using time and space resolved spectroscopy methods. The plasma flow velocity was measured by using the high speed camera. The compression plasma flow (CPF) parameters predominantly depend on the energy conversion rate from the energy supply to the plasma since the current cut-off is avoided. The maximum energy conversion rate in MPC was while operating in hydrogen (up to 70%) [2]. The experiment with MPC described in this paper is a part of our research program of construction of a two stage quasi-stationary high current plasma accelerator (QHPA) with energy input up to 1 MJ. A combination of five MPC units (input energy up to 16 kJ each) has to be used to produce fully ionized plasma at the entrance of the acceleration channel of QHPA. It was found that when QHPA is operating with the energy input of 200 kJ, the electron temperature, density and plasma flow velocity were 15 eV, 10^{18} cm^{-3} and 300 km/s, respectively, within the zone of maximal compression within the plasma flow [3]. Of special interest are applications in the plasma fusion. A specially designed plasma accelerator system was proposed as a possible plasma injector in fusion devices [2 and references there in] and magnetic traps. Another application of MPC and QHPA is in treatments of solid targets by powerful plasma flows used in simulation studies of processes which may occur at the first wall and divertor plates of plasma fusion devices.

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P6-26

Application of a soft-X ray imaging system to the STE-2 RFP

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A soft-X ray (SXR) imaging system, under development in our laboratory, has been installed in the STE-2 RFP[1,2] to obtain high-resolution two-dimensional (2-D) SXR images under various RFP discharge conditions. The purpose of the present experiment is to see if 3-D magnetic structures can be deduced from the 2-D SXR image.
The imaging system consists of a slit with a pinhole of 1 mm diameter, a microchannel plate (MCP) and a phosphor plate, both of them 20 mm in diameter, and an image intensifier CCD camera with 512x512 pixels. The plasma was viewed through a horizontal port from outer side in the major radial direction with viewing area of 10 cm diameter at the plasma center.
The STE-2 is a small RFP with aspect ratio of 4 (R/a=0.4m/0.1m). In typical RFP configuration, the safety factor is about 0.15 on axis, decreasing towards the edge to about -0.05. Thus the dominant toroidal mode numbers n of the m=1 magnetic fluctuation are in the range from 7-10. The SXR images were obtained in these standard RFP plasmas. In STE-2 RFP, internally resonant rotating helical field (RHF) was applied to study effective means for the control of MHD dynamics. The SXR imaging diagnostics were performed also in the RHF experiments together with magnetic diagnostics for MHD dynamics studies.
We have identified characteristic structures in the 2-D SXR images obtained with the present system. The observed structure appeared to show dependence on the RFP discharge conditions. Optimization of the image data processing such as noise filtering from the data or tone correction of brightness distribution is in progress to realize effective visualization of the deduced 3-D magnetic structure. Detailed analysis of the structures in the SXR images has also been carried out together with analysis of magnetic fluctuation data.

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P6-27

Development of a soft-X ray imaging system for MHD studies in an RFP plasma

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The measurement of Bremsstrahlung soft-x ray (SXR) radiation is a very useful means for diagnosing high-temperature plasmas without material insertion. Since the contours of SXR emissivity usually correspond to magnetic surfaces in a toroidal plasma for fusion research, SXR computer tomography (SXR-CT) technique has been used widely with great success in the studies of magnetic structures inside the plasma. However, one of the drawbacks of this technique is that it requires multiple CT systems in obtaining three-dimensional (3D) structures.
In the reversed field pinch (RFP), studies on the behavior of magnetic islands due to the tearing modes are quite important in understanding confinement. Since the safety factor $q \ll 1$ in the RFP, toroidal pitch of the equilibrium field is relatively short, and therefore, the SXR diagnostic system which can provide 3D magnetic structures with relatively simple components is desirable. We are developing a SXR imaging system in which a pinhole camera provides a high-resolution two-dimensional (2D) luminosity distribution on a phosphor plate through a microchannel plate (MCP). The 2D image on the phosphor plate is measured with a high-speed image intensifier charged coupled device (ICCD) camera.
We have modeled SXR emission profiles and magnetic island structures for the optical system simulation in order to specify the necessary parameters for the observation of the magnetic island structures on the SXR image. In particular, the sensitivity of the SXR images to the change in aspect ratio from 4 to 2 is of our major interest with a view to installing the system in our low-aspect ratio RFP experiment. Since the location of magnetic island is an indication of the rational surface of the corresponding mode, the results may also be used as one of the constraints for the equilibrium reconstruction.

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P6-28

Soft X-ray measurement in IRE on the TST-2 tokamak

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Spherical tokamak (ST) having aspect ratio A≤1.5 have been investigated as cost effective alternative to the tokamak fusion concept [1]. ST plasmas have some characteristic features, the avoidance of a characteristic relaxation phenomenon in ST, that is Internal Reconnection Event (IRE) [2], is one of the crucial issues to execute the stable operation. When IRE takes places, the large amount of magnetic energy stored in plasmas is converted to the kinetic energy of plasmas by magnetic reconnection process and then the stored thermal energy and particles in the core region is lost abruptly. To investigate the deformation of the plasma shape during IRE, four PIN diode arrays of 20 channels (detected region 200eV~30keV) were installed on the TST-2@K (TST-2 at Kyushu University: major radius R=0.4m, minor radius a=0.25m, aspect ratio A~1.6, toroidal field Bt=0.2T and plasma parameters are plasma current I_p~130kA, electron density $n_e \sim 10^{19} m^{-3}$ and elongation κ~1.8 [3]). In this experiment, there is feature that n and m can be determined by measurement only Soft X-ray (SXR). Precursor of IRE was observed for several milli-seconds. The fluctuation was composed of two dominant components in frequency of 10kHz and 4kHz. The mode structure of 10kHz component is n/m=1/1 structure (n/m=1/1 and n/m=2/2, where n, m represent toroidal and poloidal mode number, respectively) and 4kHz is n/m= 3/4. There is no change of frequency until precursor begins to take place and it results in IRE, but amplitude increases. The overlap of modes (10kHz and 4kHz) was considered to be cause of IRE in TST-2 from the position and the growth of the modes.

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P6-29

Soft X-ray emission profile and mode structure during MHD events in the TST-2 spherical tokamak

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In spherical tokamaks (ST), reconnection events (RE) are known to cause energy and particle losses. [1] Such events are studied on TST-2. A 20-channel PIN-diode array is used to measure the soft X-ray radiation profile during RE. With a 7μm beryllium (Be) filter, photons with lower energies (< 1 keV) are rejected. The diode array forms a pin-hole camera, and a cylindrically curved Be foil is placed just in front of the pin-hole. This arrangement ensures that incoming photons pass through the same thickness for every channel. The sightlines are tangential (toroidal) and cover the whole range of radius occupied by the plasma on the equatorial plane. Prior to RE, fluctuations around a frequency of 10 kHz were observed, especially without the Be filter. In many cases the emission intensities increased, and the fluctuations grew with a time constant of about 0.4ms. At the end of fluctuation growth, the energy loss from the central region towards the periphery of the plasma started around r/a~0.2. This is believed to be where reconnection started. In order to understand the origin of this instability the spatial gradient of the SX brightness profile is compared with non-RE discharges. When dI/dr>0.03, where I and r are SX brightness and tangency radius of the sightline, respectively, RE tends to occur against various plasma current (I_p). It was also found that dI/dr was positively correlated with $\Delta I_p/I_p$, where ΔI_p is the change of Ip at an RE. With the Be filter the SX emission increased before magnetic fluctuations started to grow. However, so far, fluctuations have not been observed in the SX emission, presumably because of the low electron temperature and the resultant low emission intensity. The ion temperature (CⅢ), however, increased by up to $\Delta T_i/T_i$~1.3, where ΔT_i is the change of the ion temperatures at an RE. This is consistent with other experiments on magnetic reconnection. [2] To survey the behavior of the spatial and temporal structures (i.e., mode structure), analysis using the singular value decomposition method is being carried out. During the growth phase of fluctuations, both symmetric (even) and antisymmetric (odd) modes were identified.

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P6-30

Soft and Ultra-Soft X-ray Detector Array Systems for Measurement of Edge MHD Modes in the Large Helical Device

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Soft X-ray (SX) detector array is widely used in various toroidal plasmas to measure MHD fluctuations. In the Large Helical Device (LHD), several 20-channel SX-detector arrays are used to observe SX fluctuations related to MHD instabilities. Control of edge MHD modes driven by pressure gradient is crucial for generating high performance plasma in LHD. For this purpose, it is important to clarify an internal structure of edge MHD mode in high beta plasmas which are produced at low toroidal field. However, usual SX detector is not necessarily suitable for monitoring plasma edge, because edge plasma is in relatively low temperature and low density and SX emission is fairly weak. Recently, three sets of 20-channel absolute extreme ultraviolet (AXUV) detector arrays have been installed inside the vacuum vessel in the vertically elongated section of the LHD to monitor fluctuations of AXUV emissions emitted from edge plasma region. The AXUV detector array has almost constant and high sensitivity in the energy range (>25eV) from VUV to SX. Moreover, the sensitivity is rapidly decreased in longer wavelength range from VUV range (< 25eV). However, it should be noted that the detector also has high sensitivity in visible light range (1.6-3.1eV).

In high beta plasmas of LHD, the AXUV detector arrays were successfully applied to detect the fluctuations related to edge MHD modes, supplementing the role of SX detector array. The low frequency fluctuations detected by these detectors have high coherence with the magnetic fluctuations of the edge MHD mode. In particular, the AXUV detector array often detects the fluctuations of edge MHD modes even in the case that the SX detector array does not detect them.

P6-31

Runaway Electrons as a Diagnostic of Plasma Internal Magnetic Fluctuations

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The edge turbulence is well characterized; it can explain the fluctuation driven particle flux, but cannot well accounts for the energy fluxes.In the plasma interior, measurements of density fluctuations suggest that electrostatic fluctuation driven transport cannot account for the observed fluxes,which makes the measurement of magnetic fluctuation important for a description of plasma confinement.There is still insufficient experimental data available to assess the importance of magnetic fluctuation for internal transport. In plasmas the measured magnetic fluctuation is too small to contribute to the thermal losses, but can explain the runaway electron transport.The difficulties in extending magnetic probe measurements into plasma precludes a study of the magnetic fluctuation levels in the plasma interior.In this study, we demonstrate the use of steady state approach and perturbation techniques to measure the diffusion of runaway electrons as a probe of internal magnetic fluctuation in plasma. Comparatively the transport of runaway electrons in plasma can be easily measured using a steady state approach for the runaway confinement time τ_r that is deduced from hard x-ray (HXR) bremsstrahlung spectra, and using the perturbation techniques for τ_r that can be deduced from simultaneously recorded sawtooth oscillations of HXR flux, soft x ray(SXR)intensity and λ=3cm microwave radiation intensity (WUW), which provide local runaway electron diffusion coefficient D_r.Assuming that magnetic turbulence is responsible for the runaway electron transport, the diffusion coefficient can be interpreted in terms of a magnetic fluctuation level.We find that the runway electron diffusion coefficient is determined by internal magnetic fluctuations rather than electrostatic fluctuations because of the high energy involved. Runaway electron behavior can be used as a probe for internal magnetic fluctuations. The value of internal magnetic fluctuationsis dependent on toroidal magnetic field. A profile of the magnetic fluctuation level in HL-2A plasma can be estimated from Dr.We can confirm that magnetic fluctuations increase from the centre to the edge.The results presented here demonstrate the effectiveness of using runaway transport techniques and steady state approach for determining internal magnetic fluctuations.

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P6-32

The Investigation of Major Disruption Based on Plasma Current Beat-wave Excitation in IR-T1 Tokamak

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The major disruption phenomenon can be seen in small Tokamak (IR-T1) shots and can cause unwanted shutdown of plasma and it can clearly be seen in the abrupt vanishing of plasma current. By means of a magnetic and a soft x-ray diagnostics it was seen that in the very short interval of disruption the temporal current beat-wave in plasma current was excited. This beat-wave can be related to the standing TE resonant modes of Tokamak cavity (Torus).

In the present paper it is shown that the excited current beat-wave is really originated from superposition of torus resonant modes and when this current beat-wave is modulated on plasma main current it can produce stimulated radiation and finally cool the plasma and shot it down.

The stimulated radiation is also investigated and it was shown that the main part of this radiation is in microwave region.

Details and results will be discussed in full paper.

P6-33

Development of a High Resolution X-Ray Imaging Crystal Spectrometer for Measurement of Ion-Temperature and Rotation-Velocity Profiles in Fusion Energy Research Plasmas*

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A new high resolution imaging x-ray crystal spectrometer (XICS) has been developed for Doppler measurement of radial profiles of ion temperature, T_i, and toroidal rotation velocity, v_φ, in plasmas. The XICS consists of a single spherically bent crystal and a two-dimensional position sensitive x-ray detector, and provides x-ray spectra from highly charged ions from multiple sightlines through the plasma. The proof of principle of the XICS was demonstrated by measurement of Ar XVII Kα spectral images from ± 8 cm of the plasma height in the Alcator C-Mod tokamak at MIT in 2003 [1] and ± 40 cm in NSTX at Princeton. However, the time resolution was limited to values >100 ms by the ~ 400 kHz count-rate limit of the available 2D detector. A new silicon pixel array detector, the PILATUS II, [2] with a count-rate capability of 1 MHz PER PIXEL and readout time of 2.54 ms, has been tested on C-Mod by recording spectra of Ar XVII at 3.1 keV. Based on these favorable results, an XICS is now being designed to measure full radial profiles of T_i and v_φ on C-Mod. The PILATUS II detector should enable T_i and v_φ profile measurements with the required spatial and temporal resolutions of 10 mm and 10 ms, respectively, and measurement of v_φ values as small as 1 km/s. The XICS concept has also been adopted for the International Tokamak, ITER, [3] and may be crucial for ITER, due to problems with other techniques. [4] An overview of important atomic data from tokamak x-ray crystal spectrometry, results of the PILATUS II tests, and progress on designs of the XICS systems for C-Mod and ITER will be presented.

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P6-34

Measurements of iron Kα lines using a wide band and compact X-ray crystal spectrometer in LHD

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X-ray spectra of Fe Kα transition array in high temperature plasmas have been obtained on the Large Helical Device (LHD) using a wide band and compact X-ray spectrometer. The spectrometer consists of a Johan-type LiF(220) (Lithium Fluoride: 2d=2.848Å) crystal with a curvature of 430mm and a back-illuminated CCD detector (Andor model DO420-BN) with a size of 26.6x6.7mm^2. A wide energy range of 6.4-7.0keV can be observed with high brightness and high temporal resolution, which enable us the measurement of Kα transitions from all charge states of Fe ions. An energy resolution of the spectrometer has been evaluated using the He-like Fe Kα resonance line from LHD plasmas and estimated to be 10eV at 6.4keV as a value of FWHM. Time-developed Kα spectra have been measured with a time interval of 10ms in the full binning mode of CCD in order to analyze the impurity transport at the central column of LHD plasmas. It is seen that the dominant charge state of Fe irons at the plasma center distributes between FeXXIII (Be-like) and FeXXV (He-like) mainly according to the central electron temperature. The impurity charge distribution is, however, significantly affected by the radial transport of Fe ions. A carbon pellet (0.9mm$^{\Phi}$×0.9mm^{L}) coated by iron with a thickness of 13μm is injected using an impurity pellet injector to confirm the brightness of Fe Kα lines and to test the signal response. The pellet with a speed of 200m/s is ablated at least within a half radius of the LHD plasma. We could see a small time delay between the rapid rise of the x-ray signals and the pellet injection. This delay means the ionization time needed for developing charge states of the injected iron in addition to the ablation time of the pellet. We report the results on Fe Kα x-ray line measurement in LHD using the wide band and compact X-ray crystal spectrometer.

P6-35

Transport study of medium-Z impurities by means of X-ray Pulse-Height Analyzer in LHD

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Associated with the spectroscopic studies of high temperature plasmas, spatial resolution is of great importance with time resolution. A spatial- and time-resolved spectrum in x-ray region is required to obtain significant information from the core plasma concerning the profile of electron temperature and the emission profile of impurities.
An assembly of X-Ray Pulse Height Analyzer (PHA) has been designed and constructed to investigate the profiles of x-ray continuum and x-ray line spectra in Large Helical Device (LHD). The assembly is equipped with a scanning system which makes it possible to estimate the radial profile of the x-ray spectrum. With the system the sight line of the PHA is scanned along the radial direction of LHD plasma. Then, the line integrated spectrum can be inverted to a radial profile using Abel inversion technique.
The radial profile of the x-ray spectrum has been successfully obtained with a spatial resolution of a few centimeters using the assembly. The radial profiles of K_α lines emitted from Ar, Ti, Cr and Fe have been also obtained. Especially, Ar K_α profiles have been measured in detail with a time resolution better than 20 ms during several identical discharges by scanning
The spatial profile of x-ray line spectrum mainly reflects the core transport of impurity. The phase-shift profile of Ar has been successfully obtained in the present study. As the quantitative study of particle transport, the radial profiles of a diffusion coefficient and a convective velocity are individually analyzed from the time-dependent phase-shift profile. In this paper the radial profiles of diffusion coefficient and convective velocity of the medium-Z impurities are reported with the experimental results obtained with the assembly in LHD.

P6-36

Development of advanced X-ray Imaging Crystal Spectrometer utilizing a large-area proportional count for KSTAR

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An advanced X-ray imaging crystal spectrometer for the KSTAR tokamak has been developed by using a proportional count. The spectrometer consists of a single spherically bent crystal and a 10 cm x 30 cm two dimensional (2D) segmented position-sensitive multi-wire proportional counter. The X-ray imaging crystal spectrometer provides spatially and temporally resolved spectra of the resonance line of helium-like argon (Ar XVII) and the associated satellites from multiple lines of sight parallel and perpendicular to the horizontal mid-plane for measurements of the profiles of the ion and electron temperatures, toroidal rotation velocity, impurity charge-state distributions, and ionization equilibrium. The segmented 2D detector with delay-line readout and supporting electronics has been utilized to improve the count-rate capability. The current fabrication status of the X-ray imaging crystal spectrometers and the initial performance test results of the segmented 2D detector will be presented.

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P6-37

Investigation of a novel X-ray tube for the calibration of the X-ray crystal spectrometer in the KSTAR machine

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A novel X-ray tube with a line filament has been developed for the in-situ calibration of the X-ray crystal spectrometer (XCS) in the KSTAR machine. The characteristics of the X-ray tube are investigated from the X-ray images of the anode obtained using a pinhole and a CCD detector. It is found that the X-ray emitting area on the anode is a slightly curved line perpendicular to the filament. The orientation and the width of the anode image are changed with the polarity of the filament current and the different anode geometry, respectively. This work may lead to the development of a novel X-ray tube with a line focus, which is required for the calibration of the XCS. Experimental results from the investigation of the X-ray tube will be presented and the technical issues on a design of the in-situ calibration system using the X-ray tube for the KSTAR XCS will be discussed.

This work is supported by the Korean ministry of science and technology under KSTAR project contract.

P6−38

A hard x-ray tomography system for the MST Reversed Field Pinch

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A CdZnTe 16 channel hard x-ray camera, with excellent sensitivity to photons in the energy range 10-200 keV, has been tested on MST. The camera extends work using individual detectors which have been used to determine the energy dependence of the fast-electron radial diffusion[1]. These detectors are immune from vibration noise and are unaffected by electromagnetic noise from rf sources. Photon counting is performed in software after each plasma discharge which allows for dynamic energy binning and excellent noise/pile-up detection. Absolute calibration of these detectors is made using the 59 keV line from Am241 source. Hard x-ray flux generated during 60 kW of launched LH wave into MST plasma is measured and shows an increase in the hard x-ray intensity in the range of 10-50 kev. Three of these detectors will be configured to form a hard x-ray tomography system. Such a system will be capable of resolving x-ray intensity in space, time and energy. The measured hard x-ray energy spectrum is used as an input to the Fokker-Planck CQL3D code to calculate the energetic particle diffusion as a function of plasma radius. This tomographic system will be placed near the LH and EBW antennas to look for signatures of energetic electrons generation and their radial diffusion. Hard x-ray contours at multiple energy ranges, and comparison with soft x-ray as well as magnetic surfaces will be presented.

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P6-39

Current profile estimation in full LHCD plasmas using Hard X-ray measurement along the top and bottom identical line of sight on TRIAM-1M

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Current profile control is a key to obtain high performance plasmas including internal transport barrier (ITB) in tokamaks. It is quite important to measure current profile in real time in order to control it. The most popular way to measure current profile has been developed by using MSE (Motional Stark Effect). High power NBI (Neutral Beam Injection) and sophisticate detection of polarized light emitted from the atomic process are required to execute the way. Especially the high power NBI is crucial for the measurement. Recently an ITB is observed in full non-inductive lower hybrid current drive (LHCD) on TRIAM-1M. As the current profile measurement is required to understand the physical mechanism of ITB, the current profile measurement in LHCD plasma is strongly required.
The current profile estimation by using HXR measurement along the top and bottom identical line of sight is proposed. As the plasma current in full LHCD plasmas is driven by the asymmetry of energetic electron distribution function, the HXR radiation along the line of sight from top is distinct from that from the bottom by the difference of the magnetic pitch angle induced by plasma current. Thus we can be estimated the magnetic pitch angle by using the HXR measurement.
The observations are executed in LHCD plasma at R-R0= 12.5cm on TRIAM-1M, where R0 shows the position of centre of the plasma. Two NaI scintillators are used for the measurement along the top and bottom identical line of sight. Each one was fixed on the radially movable support. During full LHCD discharge, the clear difference of the HXR radiation spectrum was not obtained. In the case of LHCD during ohmic heating, the difference can be observed. This suggests that the current profile around the plasma centre in the full LHCD plasma is broader than that in the OH+LHCD plasma. The difference was compared with the calculation using assumed distribution function and the current density around the plasma center in the OH+LHCD plasma was estimated.

P9-01

Measurement on spatial distribution of visible line spectra in LHD

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Spatial distributions of visible line spectra have been measured in LHD using a 50cm visible spectrometer with 26 vertical sightlines, which include emissions from inboard and outboard x-points and ergodic layer. The emissions mainly consist of hydrogen, helium and carbon. The vertical profile of visible line spectra changes with a variation of magnetic configuration, electron density and direction of NBI. In most of the cases, however, the profile has a strong peak at a sightline viewing the vicinity of the inboard side x-point. A variety of the vertical profile is reported with the diagnostic instrument on the visible line spatial distribution.

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P9-02

Spatial variation of the foil parameters from in situ calibration of the JT-60U imaging bolometer foil

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We obtain the local foil properties of the JT-60U imaging bolometer foil [1,2] (a single graphite-coated gold foil with an effective area of 9 × 7 cm^2 and a nominal thickness of 2.5 μm) such as the thermal diffusivity, κ, and the product of the thermal conductivity, k, and the thickness, t_f, of the foil by the foil calibration [3]. Calibration of the foil was made in situ using a He-Ne laser (~27 mW) as a known radiation source to heat the foil. The thermal images of the foil are provided by an IR camera (microblometer type). The parameters are determined by finite element modeling of the foil temperature and comparing the solution to the experimental results. In this work we apply this calibration technique to investigate the spatial variation of the foil parameters. Significant variation in the local temperature rise of the foil due to local heating by the laser beam indicates a spatial variation of the foil parameters k and t_f. This variation is possibly due to nonuniformity in the carbon coating and/or the thickness of the foil. In a separate work, the spatial calibration data will be used to produce the bolometer intensity data to be utilized in the tomographic analyses.

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P9-03

Tracking and Visualization of Sharp Interfaces in a Three-dimensional Plasma Simulations

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In recent three-dimensional numerical simulations of fluid phenomena, it is often required to track surfaces sharply. For example, tracking an interface between two fluids is essential in studies of two-phase flows, which appear in many physical, biophysical and engineering subjects. An important example of the surface tracking in plasma physics is the plasma-vacuum interface in a magnetic confinement fusion device. A prototype is seen in Ref.[1], in which the rational surfaces are tracked in the nonlinear MHD simulations of LHD. A difficulty in such techniques is to cover the surfaces sharply, acquiring the field information with sufficient numerical resolutions. A naive technique can bring about inappropriate motions of surfaces and intersections of surfaces which should be exclusive to each other. Aiming to apply for a numerical simulation code with sharp surface tracking, we develop a technique based on the adaptive mesh refinement approach in the combination with a molecular dynamics (MD)-like alignments of mesh elements. The MD-like mesh alignments on a surface enables us to keep the numerical resolutions of on a surface to a finite level and makes the data acquisition from the field much easier through various interpolation schemes. When the resolution on a surface is becoming poor, new meshes are generated by the technique of the adaptive mesh refinement. Since behaviors of such surface elements can be highly complicated, the development of the technique is assisted by the use of various three-dimensional visualization. Some techniques to visualize the mesh hierarchies are also developed. In the presentation, we would like to demonstrate surface simulations for mushroom-like structures formed by mutual advection of anti-parallel vortices by the techniques.

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P9-04

Nonstop Lose-less Data Acquisition and Storing Method for Plasma Motion Images

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Plasma diagnostic data analysis often requires the original raw data as they are, in other words, at the same frame rate and resolution of the CCD camera sensor. As a non-interlace VGA camera typically generates over 70 MB/s video stream, usual frame grabber cards apply the lossy compression encoder, such as mpeg-2 or mpeg-4, to drastically lessen the bit rate. In this study, a new approach, which makes it possible to acquire and store such the wideband video stream without any quality reduction, has been successfully achieved. Simultaneously, the real-time video streaming is even possible at the original frame rate. For minimizing the exclusive access time in every data storing, it has adopted the directory structure to hold every frame files separately, instead of one long consecutive file. The popular 'zip' archive method improves the portability of data files, however, the JPEG-LS image compression is applied inside by replacing its intrinsic deflate/inflate algorithm that has less performances for image data.

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P9-05

Acquisition of Data for Plasma Simulation by Automated Extraction of Terminology from Article Abstracts

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An accurate description of atomic and molecular processes in fusion edge plasma, hadron therapy of brain tumors, positron emission tomography and in other imaging fields belongs among the key factors determining the ultimate imaging resolution. Here we present a method for automated retrieval of such data from online publisher databases such as the INSPEC collection of article abstracts. In particular, a rule-based algorithm for syntactic and semantic recognition of terminology in atomic and molecular physics [1] is applied to the search of articles relevant to plasma simulation, expanding our previous work on joint search of scientific articles and self-updating databases of cross section data [2,3].

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P10-01

2D tomographic imaging of the edge turbulence in RFX-mod

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In the reversed Field Pinch Experiment RFX-mod a Gas Puffing Imaging Diagnostic (GPID) is used to investigate the turbulence of the edge plasma. The system consists of a gas puffing nozzle and 32 optical channels to measure the HeI (668 nm) line emission. The lines of sight are arranged into three fans intersecting each other in an area normal to the main magnetic field. The diagnostic system provides an analogue bandwidth of 2 MHz and all channels are simultaneously sampled at 10 MSamples/s for the whole discharge duration (350 ms).
Different inversion techniques have been applied to the data in order to obtain a 2D tomographic reconstruction of the light emission pattern from the line integrals.
Comparison shows that the most suitable method is based on 2D spatial Fourier expansion, applying the Singular Value Decomposition technique with regularisation. The high time resolution allows to obtain a 2D image every 0.1 ms.
Emission structures (“blobs”) that move along the ExB flow emerge from the background turbulence and they are characterised by computing energy and phase of the Fourier modes. A comparison is carried out between the structures identified by this 2D reconstruction and the intermittent events detected in the line-of-sight signals with a method based on the continuous wavelet transform.

P10-02

Tomographic reconstruction of emissivity profile from tangentially viewed images using pixel method

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Fast camera systems for imaging tokamak plasmas are being increasingly popular. Edge fluctuations and plasma instabilities can be imaged in the visible and X-ray wavelengths using present technologies.

While viewing the plasma tangentially, the lines of sight (LOS) pass through the plasma tangentially in 3D. Thus each LOS integrates the light through a number of flux surfaces. The present study is to build a reconstruction code for tomographic unfolding in 2D poloidal cross section of these 3D images. Here, pixel method is preferred to the analytical method to reconstruct the 2D image [1]. Poloidal cross-sectional area, where the images are to be reconstructed, has been subdivided into pixels. This pixel-grid is essentially the footprints (on a poloidal cross-section) of the micro-tori that run along the torus. Certain assumptions like toroidal symmetry of the plasma, and constant emissivity within one pixel, are taken. Say, the camera is equipped with a n x m pixel (henceforth will be called as detectors) resolution CMOS chip. Each detector sees a number of pixels along its line of sight [2]. Thus brightness (f), is given by:

$\Sigma_{i,j} I_{ij} g_j = f_i$

or, $\mathbf{I} \times \mathbf{g} = \mathbf{f}$

Where, I_{ij} is the fraction of the emission incident on detector i from pixel j and g_j is the emissivity of pixel j. I_{ij} is assumed to be proportional to the chord length of the detector i, passing through the pixel j. The **I** matrix will be populated by using ray tracing techniques which involves an attempt to find the intersection of the LOS of each detector with the micro-tori. Then using predefined emissivity profiles the brightness will be calculated. Direct inversion of **I** is not possible for **I** being badly conditioned [3]. Merits of different approaches (viz. linear regularization, minimum Fisher information etc.) will be examined (even in presence of added noise) for the estimation of local emissivity at each pixel. A suitable algorithm to develop a MATLAB based code will be reported.

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P10-03

Two-dimensional Spectroscopic Measurement of Deuterium Emission in JT-60U Detached Divertor Plasmas

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In tokamak fusion reactors, heat and particle control is one of the issues mitigating damages of plasma-facing materials. One of the most promising methods for the heat and particle control is a poloidal divertor. The volume recombination in divertor plasmas reduces the ion flux to the divertor plates. Understanding deuterium particle behavior in the divertor plasma is necessary to study the ionizing and recombining plasmas. Two-dimensional spectroscopic measurement of deuterium emission is useful to understand deuterium particle behavior in divertor plasmas, where an ionization and recombination regions exist close to each other. The information of the ionization and recombination can be obtained by measurement of deuterium Balmer-series lines. A wide-spectral-band spectrometer with a CCD detector was used to observe deuterium Balmer-series lines with two-dimensional spatial distribution in the JT-60U divertor region. The spectrometer has 92 viewing chords (vertically 60, horizontally 32) with a spatial resolution of ~1 cm. It covers a spectral range of 350-800 nm, and can simultaneously observe Balmer-series lines. From the measurement, we can obtain a two-dimensional distribution using a computer tomography technique. D_β (n=2-4, 486.1 nm) and D_γ (n=2-5, 434.0 nm) emission intensities were reconstructed with the algebraic reconstruction technique and the maximum entropy method for comparison. The D_β emission was strong above the strike point in the inner divertor and around the strike point in the outer divertor. The D_γ emission was strong above the strike point in the inner divertor.

The experimental measured emission intensity ratio, $I(D_\gamma) / I(D_\beta)$ was compared with the theoretical one calculated by the collisional-radiative model. The experimental intensity ratio around the outer strike point was less than 0.2. Since this value corresponds to the theoretical intensity ratio of the ionizing component, the D_β and D_γ emission around the strike point in the outer divertor is considered to be radiated from the ionizing plasma. The experimental intensity ratio above the strike point in the inner divertor was in the range between 0.3 and 0.5. This intensity ratio can be explained by the recombining component by assuming the electron temperature is lower than 1 eV. By assuming the electron temperature is higher than 1 eV, the ratio is considered the mixture of the ionizing and recombining component.

P10-04

Soft x-ray tomography in fusion plasmas: the Reversed Field Pinch case

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One of the major tools for laboratory plasma imaging is soft x-ray (SXR) tomography: its non-invasive nature and low-cost of its basic components, and the strong link between its output, the SXR emissivity, and important plasma quantities like pressure profiles and the shape of magnetic flux surfaces have made this technique very useful to diagnose thermonuclear laboratory plasmas.

Basically the radiative emission tomography consists in measuring the emitted radiation from a plasma region along a large number of collimated lines of sight, defined by groups of detectors and pinholes, and in obtaining the reconstruction of the emissivity from the line integrated measurements through the solution of an inverse problem. Different techniques have been developed to process the data and to perform the inversion. Tomography in fusion plasmas is a challenging diagnostics, since high time resolutions (down to tens of microseconds and to sub-cm scales in present devices, which have a typical cross section with radius of order of 1 m) must be achieved in rather difficult experimental environments (in terms of ultra high vacuum conditions, heat loads, space constraints, electromagnetic noise). This paper, after a survey on SXR tomography in magnetically confined fusion plasmas, will focus on tomographic diagnostics in the reversed field pinches (RFP) magnetic configuration [1]. SXR tomography is a particularly important tool for the RFP, since it allows to obtain information on the plasma magnetic self-organization processes, which underlay the dynamics of the configuration. In addition, the high resolutions required for RFP tomography in time and space, make the RFP an excellent test bench for the most advanced hardware and software tomography techniques. We will describe two important diagnostics, that have been developed and brought to operation in the RFX-mod and MST reversed field pinches devices. The instruments will be described, and the hardware solutions utilized to maximize the spatial and temporal resolution of the measurements will be reported. The various mathematical methods used to invert the data will be presented and applied: the images obtained show that, in both the devices, the plasma can be in two different regimes, characterized by a different degree of magnetic chaos, with evidence of coherent helical structures emerging from the chaotic plasma core. In addition, the reconstructed data can be further processed to obtain important plasma parameters, such as, for example, the electron temperature profile (“double-foil” tomography).

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P10-05

Tomographic reconstruction of internal instability in a field-reversed configuration

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A field-reversed configuration (FRC) is a compact torus consisting of a purely poloidal magnetic field. As a destructive instability which limits the configuration's lifetime, rotational instability with toroidal mode number n = 2 is only found in experimentally generated FRCs. The growth of n = 2 rotational instability can be suppressed by application of a weak multi-pole field and rotating magnetic field. However, deterioration of confinement properties as a result of the application of a multi-pole field and growth of higher-mode deformation has been observed experimentally.
In recent experiments using tomographic technique, the spatial distribution of plasma radiation (bremsstrahlung) was measured using a newly developed multi-purpose optical diagnostic system. [1] Global deformation of the cross-sectional structure of an FRC and its time evolution were investigated by a computed tomography (CT) reconstruction technique (ART method). Assuming a constant electron temperature profile, the obtained radiation profile denotes the pressure profile. These results indicated that the FRC plasma has an internal deformation of pressure profile, which has different phase from the deformation of separatrix surface. This staggered toroidal structure are difficult to be observed by spatially integrated methods, for example, magnetic probes, end-on camera and so on.
In this work, detailed features of this behavior have been investigated by a newly improved tomographic reconstruction technique. The above mentioned straggled deformation will be potentially one of the cause of deteriorated confinement in the stabilized FRC plasma by application of a multi-pole field.

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P10-06

Quantitative evaluation of tomographic resolution by coded penumbral imaging

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Penumbral imaging is a powerful imaging technique for radiations with long mean-free path. Since the reconstruction is based on deconvolution, the technique is sensitive to noise contained in penumbral images. Uniformly redundant penumbral array (URPA) technique can improve the SN ratio of penumbral images[1]. In URPA, the penumbral apertures are arranged in m-sequence and the SN ratio of the penumbral image can be improved. In the reconstruction process from the coded data, penumbral image is obtained by correlation to deconding operator. The reconstructed image can be obtained by use of the Wiener filter.

In addition, since the URPA camera can view the object with a large solid angle, it can also provide some tomographic resolution for three-dimensional object[2].

In this paper, we evaluated tomographic resolution of URPA. The tomographic resolution of the URPA has been evaluated by computer simulations.
From the simulation, it founds that half value of width of depth point spread function(DPSF) ΔZ of the URPA is $\Delta Z = 0.18 Z_0$, where Z_0 is the distance between aperture and source point.

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P10-07

Application of Tomographic imaging to multi-pixel bolometric measurements

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The measurement of plasma radiation using one-dimensional arrays with perpendicular views of plasma in a poloidal cross-section or a two-dimensional multi-pixel camera with a tangential view of plasma is a common diagnostic tool on almost all fusion devices. While the measurements from such diagnostics are line integrated, the local emission can be recovered by inverting the data using varying assumptions including poloidal or toroidal symmetry, flux surface iso-emissivity, and 1-D chordal lines of sight. However such assumptions can have an important impact on the results and it is important to make a careful and unbiased assessment of the feasibility of each assumption. Two improved tomographic algorithms in the schemes of a linear (Tikhonov-Phillips) and a nonlinear (maximum entropy) regularisation method [1], have been employed for multi-pixel bolometric measurements in order to get as much information as possible while keeping the assumptions to a minimum. The most important features of these improved methods are the capability of reconstructing radiation distributions without any symmetry assumptions, built-in smoothing, and useful reconstructions with relatively few detectors. Furthermore, the effects of finite detector size have been taken into account with a full three dimensional treatment of the detector geometry. This is necessary when the emission of the plasma has a significant variation within the field of view, especially for a tangential viewing camera system. Tests and cross-checks of the algorithms were performed using numerical phantom data sets. The application of tomographic imaging was implemented to a two-array AXUVD (Absolute X-ray UltraViolet photodiode) camera on the Large Helical Device (LHD) [2] and a two-dimensional infrared imaging bolometric (IRVB) pinhole camera on JT-60U [3, 4]. Pertinent examples of the results are presented both to illustrate the analysis techniques and to demonstrate the wealth of physics which can be studied.

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P10-08

Spherical Harmonics Decomposition in 3-D Vector Tomography

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Vector Spherical Harmonics (VSH) (as well as tensor spherical harmonics) occur in many areas of theoretical physics and engineering.
The paper is an attempt to extend the use of VSH to real computations in vector tomography diagnostics of spherical tokamak plasmas.
The problem of 3-D vector tomography is to reconstruct the vector field g(x) in some domain Ω by the set of projection data (X-- ray transform).
A method of series expansion with the aid of vector spherical harmonics intended for inverting line integrated data is proposed to investigate 3-D vector fields in the spherical plasmas.
A set of numerical computations demonstrating the 3-D reconstruction of the model vector fields has been performed to assess the inversion method proposed.

P10-09

Single Particle Analysis of Image Data Acquired by Zernike Phase Contrast Transmission Electron Microscope

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We discuss the application of Zernike Phase Contrast Transmission Electron Microscope (ZPC-TEM) to acquisition of image data for single particle analysis of biological samples.
The ZPC-TEM utilizes a Zernike phase plate [1-4] which consists of a thin film with a small hole in the center. It is positioned at the back-focal plane of the objective lens. This phase plate introduces half pi phase shift to the scattered electrons leaving the central beam of unscattered electrons intact. The resulting images exhibit much higher overall contrast due to the presence of low spatial frequencies which are strongly attenuated in images acquired using a conventional TEM. The ZPC-TEM has overall “flat” frequency response compared to the “band-pass” filter characteristics of the conventional defocus phase contrast TEM.
Data and results of single particle analysis using ZPC-TEM images are presented. They are compared to single particle analysis done by a conventional TEM. Theoretical and practical aspects in the application of ZPC-TEM are discussed.

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P11-01

Neutron Radiographic Imaging of Irradiated Fission-, Spallation- and Fusion-Materials

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1. Neutron radiographic imaging : Neutrons show an energy-dependence on neutron-material interactions. Photo-stimulated luminescence (PSL) material (BaFBr:Eu) is a radiation-photon converter material for the imaging plate(IP). The new Dy-IP (Dy_2O_3+BaFBr:Eu) has been tested by the neutron radiographic experiment for the evaluation of sensitivity, spatial resolution and quantitative characteristics as well as its realistic application for neutron radiographic post-irradiation examination of fission-, spallation- and fusion-materials. The neutron image by Dy-IP is very clear and high contrast without gamma-ray fogging. Spatial resolution is 100-300μm, which depends on its PSL layer thickness. The size and enrichment of the post-irradiated nuclear fuel rod of uranium oxide as well as the profiles of the hydrogen and/or spallation-induced product in the spallation Pb target have been visualized and numerically evaluated. By the thermal neutron radiographic techniques, however, some fusion reactor wall materials are too transparent neutron-optically to evaluate the post-irradiation effect. We must develop monochromatic cold neutron imaging technique utilizing the coherent neutron-material interaction. If monochromatic neutron imaging with variable wavelength was completed, the applications for material science and engineering may be accelerated.
2. Coherent neutron imaging of Bragg-cut-off material : Monochromatic cold neutron beam tailored by using the velocity selector has been applied to realize the coherent monochromatic cold neutron imaging. By comparing between the coherent neutron images with the longer and the shorter wavelength than the Bragg-cut-off of the iron(0.4nm), the strained part of the steel induced by welding has been visualized. This new technique may be applied for the post-irradiation examination of the fission-, spallation-, and fusion-materials. However, the tailored neutron beam by the velocity selector has a rather wide spectrum, we must prepare a monochromatic neutron beam having a much narrower spectrum.
3. Proposal and verification of monochromatic neutron imaging : We have proposed a conceptual technique of monochromatic neutron imaging. Neutron filters to obtain much narrower monochromatic neutron may be a combination of velocity selector, mosaic single crystal monochromator, Bragg-cut-off polycrystalline and critical angle-based super-mirror. Experimental tests are conducting by using the neutron beams of the TNRF and CNRF (JRR-3M, JAEA) and the NEUTRA and ICON facilities (SINQ, PSI). Results are to be presented at the conference.

P11-02

Application of the Liquid-crystal-based tunable Lyot filter to the Optical Emission Imaging Plasma Spectrometry

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The Lyot filter [1] is a kind of birefringent filter that has recently been widely employed in the spectrometry for the biochemistry, surface analysis, laser microscopy etc... The technology of this filter is based on the polarization interference whose transmittance depends on the wavelength. By cascading the Lyot filters with varying the retardation, the transmission wavelength, which is tunable by varying the retardation of the ferroelectric liquid crystal (FLC), can be selected.
We are applying this filter (Varispec: VIS-7-20) to the imaging spectrometry for the plasma optical emission. Images of the plasma for different wavelength 7 nm in each passband can be recorded via a charge-coupled-device(CCD) detector (Roper: EEV 1024x256).
After the relative intensity calibration, the intensity ratio between the images at different wavelength can be obtained for each pixel of the CCD, which enables the application of the collisional-radiative (CR) model [2] to determine electron density or temperature distribution in all the observation area.
Plasma is produced in the steady-state linear divertor/edge plasma simulator MAP(material and plasma)-II in the University of Tokyo [3].
In this paper, we evaluate the applicability of this filter to our experimental condition, selecting proper line emissions for the application of the CR-model for He I considering the radiation trapping[4], and present the preliminary results of the imaging spectrometry.

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P11-03

Development of the monitoring system of plasma behavior using a CCD camera in the GAMMA 10 tandem mirror

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High-speed CCD camera is one of very useful tools to observe precise plasma behavior and can capture the instantaneous two-dimensional (2-D) structure of its visible emission. 2-D image measurements have been successfully demonstrated in many fusion devices [1-4]. 2-D image of plasma behavior also gives us a lot of information for controlling the plasma position and understanding the plasma response on plasma heating systems.
In the central cell of the GAMMA 10 tandem mirror, a medium-speed camera (CCD camera) has been installed for the observation of plasma behavior. The framing speed of the camera is 400 frames/s. Through a horizontal port at the central-cell mid-plane, an area of approximately 40 cm×120 cm on the machine axis is imaged onto the 216×640 pixel. This camera system is designed for monitoring the plasma in the whole discharge duration. The captured 2-D images are automatically displayed just after the plasma discharges and stored sequentially shot by shot. The monitoring system is operated according to the following sequence: First, the camera, directly connected to a PC, starts to record the visible image of plasma receiving the trigger pulse. After capturing the picture images by the given frame number, the image data are transferred to a hard disc in the PC and are labeled with the corresponding shot number and then it returns to the trigger-waiting mode. The above procedure is executed by an automatic mouse control software and the data are displayed in a movie format during shot-to-shot intervals by the help of the Visual Basic software.
By using the above system, we measured the plasma behavior in several experimental conditions. In this paper, the detail of the monitoring system is described and the observed results will be discussed from the viewpoints of the difference in the wall conditioning and the dependence of a movable limiter.

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P11-04

Development of phosphor screen having "gridded energy analyzer" for two- fluid nonneutral plasma experiments

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Recently, as a passive measurement method using a CCD camera, it becomes extremely popular to estimate space distribution of plasma particle flux and temperature by photographing an emission of light from a phosphor screen on which particles or X-rays are incident. However, such a conventional method cannot distinguish ions from electrons. Also, it usually equips no function of analyzing particle energy.

In this paper, we propose a new type of phosphor screen which can analyze particle energy. This new method clearly has an advantage of clarifying both space distribution of number density n and particle energy E simultaneously. Thus, this may answer how both n and E are evolved in two-fluid nonneutral plasma experiments.

The proposed device is as follows; It has three potential grids in front of a phosphor screen. The first grid facing a plasma is made of a metal-mesh that is grounded. The second grid is also made of a metal-mesh to which variable potential is applied, for analyzing particle species and energy. Thus, particles having higher energy than the potential applied to the second grid can reach the third grid. The third metal-mesh can be energized at either positive or negative high voltage (up to 10 kV) in order to accelerate either ions or electrons which have passed through the second grid, respectively. Then, the accelerated particles hit the last fourth grid that is composed of the handmade phosphor screen. Regarding to the screen, its diameter is 10 cm, and on the surface (made of a quartz plate) we apply fluorescent (Zn; ZnO) emitting green light (the wavelength is 505 nm). This alleviates the difficulty in distinguishing the signal line from the shining background emission of the tungsten filament. On the surface of the fluorescent is covered with an Indium Tin Oxide (ITO) film with about 0.1μm thick. Thus, its potential can be always set several ten volts higher than the third grid potential for secondary electron suppression. Finally, to detect the emitted light from the phosphor screen, an ICCD camera (DH520-18F-01-I) made by Andor is installed.

In this conference, the detail of the new proposed instrument and an initial data will be presented.

P12-01

Imaging challenges in long pulse nuclear fusion experiments

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The strong move of high power nuclear fusion experiments towards quasi-continuous operation, creates new challenges regarding the design of imaging diagnostics as well as image data storage, retrieval and analysis.
In the examples presented the focus will be on developments for non-burning plasma devices in which, on the diagnostic design side, one needs to cope with high heat loads, contamination of the first optical element and strong ECRH stray radiation. To demonstrate one way of how to cope with the design problems, the optical design strategy for an IR/visible imaging endoscope for continuous divertor control and divertor plasma physics investigations at the W7-X stellarator, will be elaborated on, but also the strategies followed on other devices will be discussed. On W7-X the IR divertor monitoring systems are combined with an even larger number (~15) of high spatial resolution CCD cameras equipped with interference filters for divertor plasma symmetry and physics investigations and a further 10 digital cameras with toroidal views into the plasma vessel to monitor any interactions of the plasma with the water cooled wall panels and any other special in-vessel components.
A further, very stellarator specific imaging diagnostic, is the flux surface measurement where a beam of electrons is injected either into vacuum to produce bright spots on a fluorescent rod moved across the vacuum vessel, or by injecting them into a gas filled torus to visualise the beam path around the torus. Comparison of these measurements with vacuum magnetic field calculations, gives detailed information on the actual magnetic field structure. Identifying the washed out electron beam path in a gas with high accuracy via image processing resembles very much the tracking of veins or arteries in medical images.
The high data rates, as well as the total storage requirements of ~15 GByte per 30 minute discharge, of which on W7-X it will be possible to run two per day, are expected to be manageable by 2012 when the device will start operation. A major challenge till then will be the development of fully automatic pattern recognition and classification software to build a hierarchical system of increasing level of abstraction with respect to patterns in individual images as well as image sequences. Due to the fuzziness of the images the methods that need to be developed will tend to be different from those presently developed in other non plasma physics communities. Since the retrieval of the image data of complete pulses will no longer be meaningful nor desirable, sensible fully automatic film sequencing as well as variable resolution retrieval, matched to the respective needs, will be of high importance.

P12-02

Observation of toroidal asymmetric radiation in the Large Helical Device

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In helical devices, a magnetic configuration does not have toroidal symmetry and thus plasma radiations are localized poloidaly and also toroidaly. An influence of asymmetric radiations is important issue for a precise estimation of the total radiated power loss on the power balance equation in the current devices. For a design of future helical devices, such as the force free helical reactor (FFHR), it is also important due to an avoidance of damage on the first wall by a localized high heat flux.

For the diagnosis of the total plasma radiation, several bolometry systems are used in the Large Helical Device (LHD)[1]. Resistive bolometers are the main diagnostics for measuring the plasma radiation. The total radiation is measured method on the local area for toroidal direction and is estimated using a volume of this field of view (FOV). An infrared (IR) imaging bolometer is a two-dimensional diagnostic system for measuring the plasma radiation [2-3]. At typical discharges, a local radiated power is kept a toroidal symmetry, and then the total radiation and a local radiated power show a similar phenomenon. But the localized high radiation region by injected impurity pellet was also measured and in this case IR imaging bolometer observed a toroidal asymmetric radiation.

In this paper, we discuss a comparison of a local radiated power and the total radiation using different borometry systems and investigate an influence of a local radiated power in LHD.

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P12-03

Effects of face contour and features on occipitotemporal activity when viewing eye movement

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Introduction: In our daily life, it is important to recognize the facial movement. We have reported that the occipitotemporal area, corresponding to human MT/V5 region, is activated by viewing facial movement. However, the question still remains whether the MT/V5 activity is influenced by face configuration and features. We investigated the differences between eyes and dots movements in MT/V5, using magnetoencephalography (MEG).
Methods: We studied thirteen right-handed subjects. We used apparent motion and compared two stimulus conditions as follows; (1) **CDL**; a schematic simple face made by a configuration (Circle), eyes (two Dots) and mouth (horizontal Line) was presented and two dots averted in an instantaneous transition. (2) **D**; A configuration and mouth were removed from **CDL**. Subjects described a simple movement of dots for **D**, but eye movement for **CDL**, though movement modalities were the same through both conditions. We estimated the single source for the evoked magnetic field in the occipitotemporal area by using the single dipole model method.
Results: A clear component peaking at around 180 ms, 1M, was identified around the right and left occipitotemporal region following both **CDL** and **D** movement, respectively. Dipoles in both conditions were estimated in the occipitotemporal region, MT/V5, and there was no significant difference of their location between both conditions. There were no significant differences of peak latency between two conditions, but the maximum dipole moment in **CDL** was significantly larger than that in **D** ($p<0.01$). There were no inter-hemispheric differences in either peak latency or maximum moment.
Discussion: These results indicated that there is the specific process of facial movement information in MT/V5 and this activity is influenced by face configuration and features. We consider that the presences of face configuration and features play an important role for human in perception of face movement.

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P12-04

Neural mechanism for processing of biological motion perception: An event-related potential study

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Biological motion (BM) is well known and interesting phenomenon that we can get vivid impression of human figure just from only moving point-lights. Recently, it is discussed in the context of social perception (e.g. [1]). As supporting this notion, neuroimaging studies have revealed that the same region responsible for the BM perception activates as other social perception (e.g. gaze direction). However, the neural dynamics for the processing of the BM perception is unclear.
To clarify the neural dynamics involved in the perception of BM, we recorded event-related potentials from twelve healthy adult subjects. The subjects were shown BM or scrambled motion (SM) as a control stimulus. In the SM, each point had the same velocity vector as in the BM, but the initial starting positions were randomized. The perception of both BM and SM elicited negative peaks at around 200 (N200) and 240 ms (N240). Furthermore, both negative peaks were significantly larger in the BM condition than in the SM condition over the right occipitotemporal region. In light of previous human neuroimaging studies, we speculate that component N200 is generated near the extrastriate cortex area and N240 is generated from the superior temporal sulcus region.

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P12-05

Centrifugal regulation of human cortical responses to a task-relevant somatosensory signal triggering voluntary movement: An MEG study.

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Many studies have reported a movement-related modulation of response in the primary and secondary somatosensory cortices (SI and SII) to a task-irrelevant stimulation in primates. In the present study, magnetoencephalography (MEG) was used to examine the top-down centrifugal regulation of neural responses in the human SI and SII to a task-relevant somatosensory signal triggering a voluntary movement.
Nine healthy adults participated in the study. A visual warning signal was followed 2 s later by a somatosensory imperative signal delivered to the right median nerve at the wrist. Three kinds of warning signal informed the participants of the reaction which should be executed on presentation of the imperative signal (rest or extension of the right index finger, extension of the left index finger). The somatosensory stimulation was used to both generate neural responses and trigger voluntary movement, and therefore was regarded as a task-relevant signal. The responses were recorded using a whole-head MEG system.
The P35m response around the SI was reduced in magnitude without alteration of the primary SI response, N20m, when the signal triggered a voluntary movement compared to the control condition, whereas bilateral SII responses peaking at 70-100 ms were enhanced and the peak latency was shortened. The peak latency of the responses in the SI and SII preceded the onset of the earliest voluntary muscle activation in each subject. Later bilateral perisylvian responses were also enhanced with movement.
In conclusion, neural activities in the SI and SII evoked by task-relevant somatosensory signals are regulated differently by motor-related neural activities before the afferent inputs. The present findings indicate a difference in function between the SI and SII in somatosensory-motor regulation.

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P12-06

The magnetoencephalographic neural activity related to the perception of apparent motion defined by various cues

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Although several theoretical and psychophysical studies have suggested the distinct neural process for the perception of 2nd-order motion different from that for the 1st-order motion, few physiological studies have supported this idea. We investigated whether magnetoencephalographic (MEG) neural responses to the apparent motions (AM) defined by various 2nd-order (luminance-independent) cues (2ndAM) are different from that defined by 1st-order cue (1stAM). MEG responses to the 1stAM and the three 2ndAMs(contrast, texture, and flicker) were measured from 6 subjects using 306-channel detectors array (Vectorview; ELEKTA Neuromag, Finland). The response properties (peak latency and amplitude of the first response component) for the 1stAM were significantly different from those for the 2ndAM except for contrast-defined AM. The response to each 2ndAM had different properties among each other. When the 1st-order cue was added to the 2ndAM, the response properties changed markedly. The response sources for all the stimuli were estimated to be around MT/V5+ of each subject. The results correspond to the notion that the neural process for the 2ndAM is different from that for the 1stAM. Furthermore, there may be no unique mechanism for the perception of all 2ndAMs, although processing of each AM perception may use a common neural circuit to some extent.

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